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CONTENTS.

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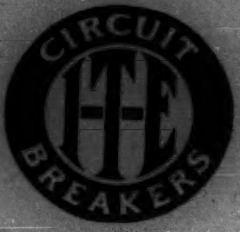
To the Electrical Engineer.



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OF THE

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS.

Vol. XXI. JUNE, 1904. No. 6.

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DISCUSSION ON "CONTRIBUTION TO THEORY OF THE REGULATION OF ALTERNATORS" AND "THE MECHANICAL CONSTRUCTION OF REVOLVING-FIELD ALTERNATORS."

C. A. ADAMS, JR.:—Owing to the difficulty of checking the specified regulation of a large alternator by direct test, many efforts have been made to devise an indirect test which shall be reliable, simple, easily applied under shop or installation conditions, and shall involve the least possible calculation.

The two[1] methods most commonly used during recent years fairly satisfy all these conditions except the first, which is the most important, and which, as has already been pointed out, they do not at all satisfy except with particular types of machines. They both require the observed saturation and short-circuit curves.

The method of which the above named are special cases, called by the speaker the General Method,[2] requires the same two observed curves, involves considerably more computation, but is far more reliable.

Behrend's method of opposing the two halves of the field with unequal currents is ideal in many respects, although the speaker has not as yet tested it experimentally. Its application, however, appears to be limited to machines with a large number of poles, although some method of correcting the error due to a small number of poles may be devised. This method is obviously inapplicable to any of the machines with single field-coil.

The method of Messrs. Hobart and Punga requires only the saturation curve, and is otherwise a complete predetermination involving a very considerable amount of calculation. From the single example given by the authors, it appears to give good results as a means of determining the excitation and regulation. This is, however, a very narrow experimental foundation, and the speaker would like very much to see the method applied to other types of alternators. Even though this method should fulfil all of the author's expectations, it is nevertheless decidedly unsuitable as a check on specified regulation, since it is primarily a method for predetermination, a method for the designing engineer. It takes account of one generally neglected factor, the effect of the ratio or pole arc to pole-pitch, and gives a very interesting method of analyzing armature reaction, an objection to which, however, is the "cut and try" process involved in its application.

There are several statements which require special attention.

1. The authors start out by assuming that all other methods give inaccurate results for "different types of machines."

1. The e.m.f and m.m.f. methods, or, as Mr. Behrend has most appropriately called them, the pessimistic and optimistic methods.

2. *Harvard Engineering Journal*, 1902–03. The speaker makes no claim to originality in this method, as it is the direct application of the methods of analysis used in connection with transformers and induction motors for at least ten years.

The method referred to above as the "General Method" has been in use by the speaker for several years and has been applied to a variety of types. In no case where the experimental data were reliable, have the observed results differed in an important degree from those calculated by this method. The types tested include revolving field, inductor, and a machine with a closed coil, three-phase armature. This last was a very trying case, owing to the three-belt armature winding, each belt occupying 120 electrical degrees of the armature surface.

Some of the results referred to are given in the accompanying table taken from the *Harvard Engineering Journal* for April, 1903. Column *A* gives observed results; B, calculated by "General Method"; C, e.m.f. method; and D, m.m.f. method. Machine No. 1 is a G. E. 50-kw. revolving-field alternator with

Machine.	Non-inductive Load.								
	Full Load Excitation.				Regulation %.				Power-Factor.
	A	B	C	D	A	B	C	D	
No. 1	15.1	15.4	15.7	15.2	9.8	10.5	12.7	10.1	.8
No. 2	150	149.5	171	147.3	4	3.9	8.4	3.4	.8
No. 3	80.8	79.5	87	72.6	7.4	7	9.8	3.9	.8
No. 4	—	—	—	—	—	—	—	—	.9
No. 4	132	139	197	131	4	5	12	3.8	.7
No. 5	141	139.5	146	134.5	5.5	5	7.3	3.9	.85
No. 6	2.99	2.97	3.07	2.89	23.8	23.5	25.9	21.05	.75

Machine.	Inductive Load.								
	Full Load Excitation.				Regulation %.				Power-Factor.
	A	B	C	D	A	B	C	D	
No. 1		20	24.5	19.6		31.5	46	31	.8
No. 2		200	350	181.3		14.5	36.2	10.1	.8
No. 3		146	250	84		24.5	36.3	8.6	.8
No. 3	108	107	127.5	76.5	19.3	18.8	23.8	8.4	.9
No. 4	200	206	400	158	14.8	15.5	49	9.1	.7
No. 5	168	169	220	146	13.6	14.	23	6.8	.85
No. 6	3.89	3.91	4.52	3.58	46.6	47.	57.5	39.5	.75

practically no saturation; No. 2 is a G. E. 1500-kw. revolving-field alternator with moderate saturation; No. 3 is a 750-kw. Stanley inductor alternator with high saturation; No. 6 is the closed-coil machine mentioned above; No. 4 and No. 5 are European machines the data for which were taken from published tests. In the other cases the tests were made with great care under the personal supervision of the speaker. It is not claimed that this method is theoretically as sound as that of Messrs. Hobart and Punga, but simply that it does give good results.

2. The authors claim on the first page of their paper that their method is free from hypothetical assumptions is doubtless intended only as a relative claim, since they have eliminated only one or two of the numerous assumptions and approxima-

tions ordinarily made use of to simplify this naturally complex problem. One assumption which has a particular bearing on this method is that the air-gap is constant under the whole pole-face, which is often not the case, the pole pieces being backed off at the edges in order to produce a desired wave shape. The result of this is to reduce the effective pole width by an amount only determinable by laborious calculation.

3. The authors have placed cross-magnetization where it belongs, although the same end is obtained vectorially with much less trouble and a little less theoretical accuracy in the "General Method."

4. The relative importance of the leakage reactance as compared with the armature m.m.f. is somewhat underestimated by the authors, at least the example given is not an average one in this respect. This relative importance is measured by the ratio, at short circuit, of field m.m.f. to armature m.m.f., which is from the example given, 1.16. The speaker has worked this out for a number of typical cases, where it was found to vary from 1.1 to 2, the highest values occurring in inductor alternators.

5. The author's suggestion as to specifying regulation at a low power-factor rather than at power-factor = 1, is in accord with opinions expressed in these meetings, and points to Mr. Behrend's field-bucking method as the best check in the case of large, many-pole alternators.

Remembering that it is the wattless component of the current which has the greatest effect upon regulation, the following table makes very clear the reason why a small deviation of the power-factor from unity makes such a great difference in the regulation, whereas a considerable deviation from zero makes practically no difference.

Power-factor	0.995	0.99	0.98	0.90	0.20	0.10
Wattless component	0.10	0.14	0.20	0.435	0.98	0.995

B. A. BEHREND:—We designing engineers, and men in charge of manufacturing concerns, receive specifications from the consulting engineers, which call for a regulation of say, 6, 7, 8, 9, 10, or 11% on a power-factor of 100%. Who among you has ever made a test on a large unit on a power-factor of 100%? The speaker has never had the pleasure of being able to get 1000 kilowatts of load with a 100% power-factor. Experiments of this nature are confined to small units of 100 or 200 kw. in which the load may consist of German-silver strips wound non-inductively. A water load is a load which may have considerable electrostatic capacity. This was pointed out 30 years ago by a venerable German teacher, Professor F. Kohlrausch, by passing an alternating current through an electrolyte. Now, if there is a very small electrostatic capacity, there is a small leading current, and a small leading current represents a current magnetizing the armature, and you may say after your test is made that the

machine is the best you ever saw—that the regulation is 3.5%, while we know it is 7%. This is also the reason why it has often been said that the regulation of the inductor type of alternator is so satisfactory, because when it is tested on a water load it is easy to obtain excellent regulation. Tests on large units at 100% power-factor are a farce. It is next to impossible to measure accurately a power-factor at 100% and we therefore have to confine ourselves to the determining of the regulation under conditions which can be determined by actual experimental test. Such tests can be made on a power-factor of zero at which the regulation can be actually measured. By using two machines, one as a synchronous motor and one as generator, such regulation tests can be obtained. The speaker indicated half a year ago how, by splitting the fields, such regulation curves may be obtained on a single machine, and fairly accurate regulation and heating data may be secured. More and more, prominent engineers seem to realize the importance of a regulation at low power-factors, as has been indicated since reading the writer's paper a year ago, by expressions from Mr. W. L. Waters, and now from Messrs. Hobart and Punga. But the regulation on zero power-factor does not give the regulation on 100% power-factor, even if, as Mr. Hobart says, you specify the ohmic drop, and the ratio of pole-arc to pole-pitch, as you may shape the saturation curve so that you get, for instance, a regulation of 5% on purely inductive load, and a regulation as poor as 10% or as good as 4% on non-inductive load.

It appears to be wise to admit the existing dilemma. The question of accurately determining the regulation of alternators cannot be solved. Many questions in natural science are not capable of an accurate solution. Let us acknowledge our ignorance instead of trying to deceive one another that we know something which we do not know. It seems to the speaker far more dignified and more in accordance with the science that we are working in, to say that this case is so complex, so intricate, there are so many factors to be taken into account, that it can no more be solved than you can state to one-thousandth of an inch the distance between two chalk marks drawn on the floor.

W. L. WATERS (*by letter*):—This theory of the regulation of alternators hardly seems to possess that freedom from hypothetical assumptions that Mr. Hobart claims for it. Mr. Hobart commences accurately enough by classifying the self-induction lines linked with the armature winding into three groups;—the lines across the slot itself, the cross-magnetization lines, and the back-magnetization lines. But he then makes the statement that it is more accurate to neglect the cross magnetization lines as they have practically no resultant effect. Mr. Hobart has apparently confused the variation of the armature self-induction lines, due to the rotation of the magnets

with the variation of those lines as the armature current follows a sine function all the time. In considering the cross-magnetization lines, Mr. Hobart considers them as being fixed relatively to the pole piece and swept across the armature conductors, as the pole piece moves past them. He seems to forget that these lines are an integral part of the self-induction proper of the armature, just as much so as those lines linked only with the slot and that often they form the greater part of the armature self-induction lines.

Some years ago while working on the question of regulation of alternators, the writer made numerous experiments, measuring the self-induction of alternator armatures under various conditions. And the following figures taken from the tests on a large number of machines show very well the proportion that these cross-magnetization lines bear to the total self-induction lines in standard alternators.

The table gives the self-induction per unit length of the armature. "A." when the armature stands alone, the magnets not being in position, and "B," when the magnets are in position and the armature winding opposite the center of the pole face.

No.	Machine.	Self-Induction of Armature. Position "A"	Position "B"
1	300-kw. 60-cycle	34	60
2	450-kw. 60- "	59	93
3	500-kw. 50- "	78	120
4	50-kw. 40- "	35	78
5	75-kw. 50- "	24	50
6	400-kw. 60- "	38	94

Position "A" gives practically the self-induction of the slots alone, while position "B" gives the self-induction of the slots and the cross-magnetization lines. It will be seen that the total self-induction of the coils averages about double that due to the flux in the slots alone.

At the time of making the above tests, the writer tried calculating the regulation of these alternators on non-inductive load by figuring the self-induction e.m.f. from the self-induction given in position "B" and simply taking this e.m.f. in quadrature with the main armature e.m.f. A comparison of the calculated and actual test results are given in the following table:

Machine.	Regulation Per Cent. Actual Test.	Calculation.
No. 1	7.4	8
2	6.1	5.2
4	9.4	8.3
5	8.7	8.5
6	7.0	7.1

The method appears to give fair results. But it is very evident that, if in addition, we tried to take into account the back ampere-turns on the armature, the calculated results would differ greatly from the actual test figures. And if the

cross magnetization was taken into account by Mr. Hobart on the 850-kw. alternator he describes, the calculated and test regulations would show a wide discrepancy.

Mr. Hobart's method should be added to the list of empirical methods and when the various coefficients have been determined by experiments on a number of machines, it will probably be capable of giving good results in practice. The calculation of the short-circuit current of an alternator cannot be considered as a test of any theory. A single coefficient to give the armature reaction effect is all that is required, and this coefficient varies only very slightly with the different standard commercial designs, so that the short-circuit current is the simplest calculation to make in connection with an alternator. The real test of any theory is to calculate the regulation of an alternator on inductive loads. In connection with this the writer thinks Mr. Hobart is doing service in again emphasizing the advisability of guaranteeing regulation on a low power-factor, preferably on power-factor zero, rather than on non-inductive load.

Probably the most important point in Mr. Hobart's theory is the way in which he takes into account the effect of the increased leakage caused by the back ampere-turns on the armature. This increased leakage has been mentioned before as being detrimental, but this is the first time that any method of calculating the effect has been published. Mr. Hobart deserves due credit for emphasizing this point.

C. A. ADAMS, JR.:—The speaker wishes to take exception to the last statement in Mr. Waters' communication. The method employed by Messrs. Hobart and Punga for taking account of the extra leakage was described by the speaker in detail in the *Harvard Engineering Journal*, November, 1903; and January, 1904. Even the approximate method of getting the air-gap line by drawing a tangent to the lower end of the saturation curve was there explained.

B. A. BEHREND:—The speaker wishes to take this opportunity to make good a sin of omission of which he feels guilty in connection with his paper presented a year ago. Professor Alexander Potier published some four years ago a theory based on tests on alternators, which the speaker placed at his disposal, which is substantially the same as that suggested by Professor Adams,—the one used in the speaker's paper and the one which it is believed has found its way into almost all the calculations of designing engineers; namely, the splitting of the armature reaction into two components, one pure reaction and the other pure reactance. The speaker wishes to go on record as giving Professor Potier credit for his part in this work.

GANO S. DUNN:—In the absence of the authors, Mr. Dunn presented the paper by Messrs. Hobart and Punga and called attention to points which he thought they would wish to make were they present. He said in answer to Mr. Waters' discuss-

ion that as he read the paper, the authors did not take the position that the lines linked with the armature conductors, never emerging from the armature, following path *l*, are really the only lines that should be included in the calculation of the armature's inductance. Hobart and Punga's paper said:

"An interesting point to be noticed in the short-circuit current relates to the very small value of the reactance pressure as compared with that generally ascribed to such proportions. This arises from the elimination of all fluxes emerging from the armature, the remaining flux being in our opinion the only one correctly to be considered as pertaining to the reactance pressure."

This would mean, taken in connection with statements later in the paper, that the authors are willing to admit that the calculation of the absolute inductance of the armature by itself should not be limited to the lines in path *l*. In the present method of determining the regulation of machines, the lines in the other two paths are merely not classed as self-inductive but as distortive. They are not neglected, however, but are taken care of in the calculation of the distortion constant.

In response to Mr. Behrend's remarks in regard to the necessity for including the degree of saturation of the magnetic circuits as a factor in the problem of regulation, Mr. Dunn pointed out that although not considering this as important a factor as did Mr. Behrend in his paper on the subject, they had included it as could be seen by reference to Fig. 14 where the excitation curves were given for a large number of particular pressures.

Mr. Dunn expressed appreciation of Mr. Behrend's views in his book on induction motors, and also as given verbally to the meeting, to the effect that engineering and designing of the kind under discussion, was not a science but an art. It required the consideration of innumerable factors, many of which were human rather than mathematical, and one should go at the business of designing without being too tightly hampered by purely physical or purely mathematical considerations.

Mr. Dunn inquired in reference to Mr. Rushmore's paper, whether the author had ever used and whether he approved elastic spokes for holding the revolving rings of generators—a spoke that permits the bursting strain to be taken by the ring as an annulus and not by the spokes in longitudinal tension.

DAVID B. RUSHMORE:—In reply to Mr. Dunn's question the speaker would say that most of the high-speed machines which have been shown this evening are so constructed that the rims are self sustaining, the purpose of the dove-tails and arms being simply to drive the outer rim. These rims are built up of laminated steel sheets riveted together.

The regulation of alternators is a very important subject, both to the designer and to the operator. The importance comes not so much as a question of what change in pressure

will take place under certain conditions, as it does with regard to the necessary change in exciting conditions to sustain the pressure under these varying loads and power-factors. Unless a large margin is left in the generator field rheostat or in the exciter pressure, and the iron is worked well below the knee of the saturation curve, it is necessary to predetermine the relations which will hold in the generator between the exciting current and the exciting pressure and the pressure, current, and power-factor of the armature load. It may be of interest to state that the regulation of alternators can now be predetermined for all conditions within the limit of commercial necessities.

It is possible that the speaker does not quite understand Mr. Behrend's remark about obtaining the actual regulation of an alternator of large output at unity power-factor, but a short time ago the actual regulation at unity power-factor and at other power-factors, both lagging and leading, was obtained on a generator of 3500-kw. output. In this particular case the actual results were in very close agreement with the estimated values.

GANO S. DUNN:—Replied that the spoke Mr. Rushmore described was not an elastic spoke, but a loose one, and said he had found such a construction bad, especially in the case of a laminated ring, because it was impossible to shrink the ring on or in other ways to make it fit the spokes tightly, and there was in consequence considerable play as a result of the clearance necessary in assembling. When the centrifugal forces came into play this clearance made the ring slightly loose on its spider, and this slight looseness increased with wear, with very bad effects. The elastic spoke referred to was for the object of permitting the ring to yield away from the center a slight amount sufficient for it to take up its own strain and yet to keep it sufficiently rigidly bound to the hub to avoid looseness.

F. A. C. PERRINE:—Mr. Rushmore showed one picture in which that was described exactly. It was a revolving field which had a smooth, uniform rim bolted to spokes with extended ends; the spider construction not being continuous. These rims are bolted to the spoke with a bolt that is capable of extension so arranged as to produce the elastic spoke which Mr. Dunn has spoken of. This theory was discussed about four or five years ago in connection with some high-speed water-wheel plants, and the bolt construction was adopted at that time.

BRADEY T. MCCORMICK (*by letter*):—In considering the subject of regulation of alternators, it may be of interest to note a simple graphic method by which the regulation for any current and power-factor can be obtained, when the saturation curve is given and the load characteristic for the same value of current at zero power-factor.

Fig. 1 is a vector diagram of an alternator, which hardly needs explanation.

E = terminal pressure.
V = pressure to which machine would rise if the load were removed.
L = inductance drop.
R = resistance drop.
A = drop due to demagnetizing effect of armature reaction.

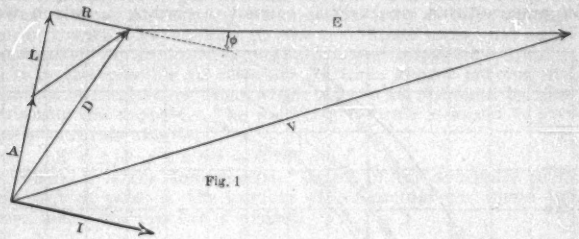


Fig. 1

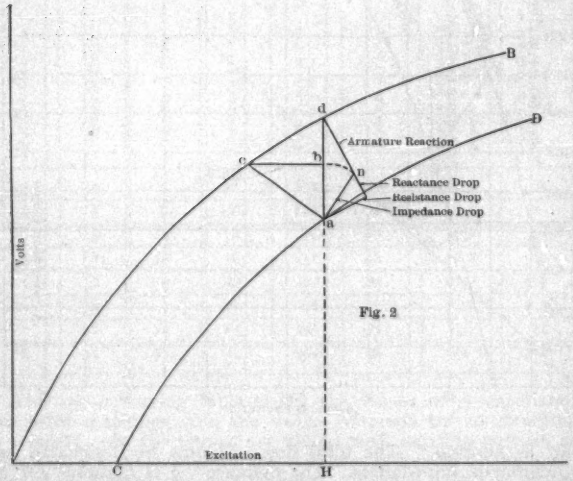


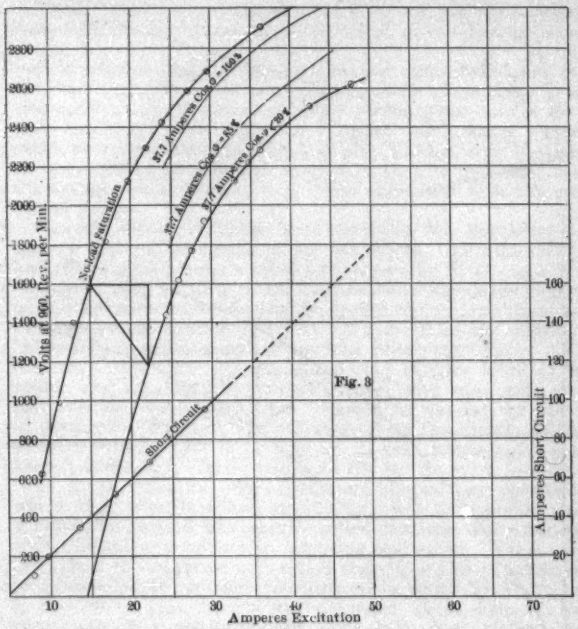
Fig. 2

I = current.

The armature reaction component A is represented in quadrature with the current since, like reactance, its effect is maximum when the power-factor is zero.

Let $A\,B$, Fig. 2, represent the saturation curve and $C\,D$ the regulation curve at zero power-factor. For any excitation

such as $A\ H$ the drop is $a\ d$ [1] and may be made the hypotenuse of a right triangle, as in Fig. 1, with the resistance drop as one leg, and the reactance drop plus armature reaction drop as the other. As the resistance is relatively small, no great error will result by swinging the impedance pressure n around to b and considering the distance $b\ d$ as armature reaction drop, instead of $n\ d$, $b\ c$ will then be the armature reaction expressed in ampere-turns, or exciting current, according to which we



plot as abcissas.[2] The total drop $a\ d$ may be designated as synchronous impedances. The distance $c\ b$ is constant for a given current, no matter what position along the curve it may

1. The diagram is not strictly correct since the drop $a\ d$ is represented in phase with $H\ d$. Fig. 1 shows that the total drop D can not be in phase with V, even at zero power-factor, unless the resistance is zero. However the resistance is small, so no appreciable error results.

2. "Experimental Basis for the Theory of Regulation Alternators," paper read by Mr. B. A. Behrend before the INSTITUTE May 19, 1903

have, so also is $a\,b$. However the distance $b\,d$ is not constant for a given current but depends upon the position on the curve (*i.e.*, is dependent upon the degree of saturation). Since $a\,b$ and $b\,c$ are constant, the hypotenuse $a\,c$ is also constant, and from this it follows that having the two, curves $A\,B$ and $C\,D$ given by experiment, if we can by trial find a line such that its direction and its length between the curves is constant, as we move it along the curves, we may construct a right triangle upon it, with legs parallel to the coördinate axes and equal respectively to armature ampere-turns and impedance drop.

It is also possible to calculate $c\,b$ from known current and number of conductors, from which $a\,b$ can be obtained by constructing the triangle. The following formula is found to give fairly accurate results.

$$A = 1/2\sqrt{2}\,a\,n\,I = 0.707\,a\,n\,I.$$

Where A is the demagnetizing effect of the armature turns per pair of poles a, the number of conductors per phase per pole, and n the number of phases.

Number of Machine.	Number of Phases.	Number of Poles.	Conductors per Phase per Pole.	Field Turns per Pair of Poles.	Armature Amperes.	Armature Reaction Expressed in Exciting Amperes = $\frac{0.707\,a\,n\,I}{\text{Field Turns}}$	Value of Armature Reaction Observed from Curves.
1	3	8	15	213	239	35.7	38
2	3	8	48	512	37.7	7.5	—
3	3	72	32	89	30	22.9	24
4	3	20	36	141	55	29.8	32
5	3	6	48	420	26	6.3	6.5
6	2	4	192	704	20.5	7.9	8.2
7	2	26	64	205	25	11	11
8	2	16	72	254	38	15	13.5

The accompanying table shows the values of A calculated for eight machines, also the values obtained by constructing a triangle. As the curves are ploted with exciting current as abscissas the expression for ampere-turns is divided by the number of field turns per pair of poles. In each case the proper triangle was found by trial. In most machines the hypotenuse of the triangle makes an angle of about 45 degrees with the coördinate axes. Figs. 3 and 4 are the curves for machines numbered 2 and 3. The saturation curves and curve for power-factor less than 20% have been ploted by results obtained when the machines were tested. The latter curve was obtained

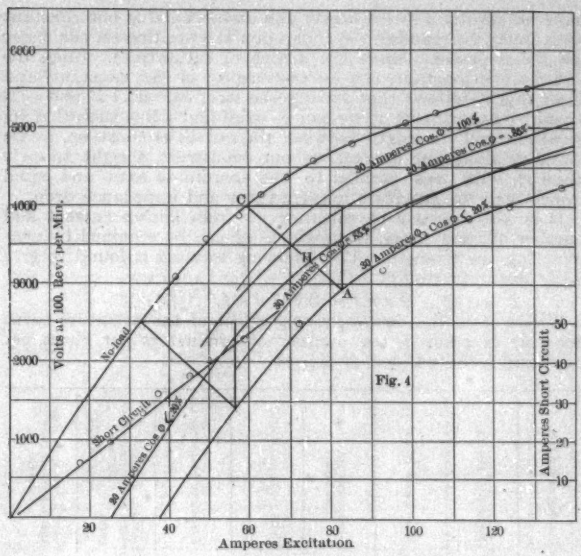

6000
5000
4000
3000
2000
1000
Volts at 100 Rev. per Min.
20
40
60
80
100
120
Amperes Excitation
50
40
30
20
10
Amperes Short Circuit
No load
Short Circuit
20 Amperes Cos θ = 100%
20 Amperes Cos θ = 85%
20 Amperes Cos θ = 70%
20 Amperes Cos θ = 50%
20 Amperes Cos θ < 50%
C
H
A

Fig. 4

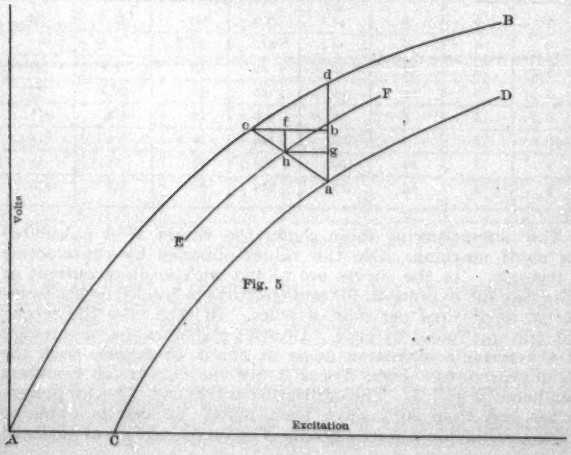

B
d
F
D
c
f
b
g
h
a
E
Volts
A
C
Excitation

Fig. 5

by loading the generator with an under-excited synchronous motor. It is impossible to obtain a strictly wattless load, but when the power-factor is below 20% the error in considering it as zero is very small.

Suppose we have the regulation curve for I amperes at zero power-factor, $C\,D$ Fig. 5, and wish to find the curve for some other value of current; for example I/x, at zero power-factor. Both armature reaction and impedance drop are now $1/x$ of their former value. Lay off $c\,f = c\,b/x$ and $b\,g = b\,a/x$. Construct triangle $c\,f\,h$. Now as the line $c\,a$ moves along the curve, the path traced by the point h will give the desired curve $E\,F$ for I/x amperes.

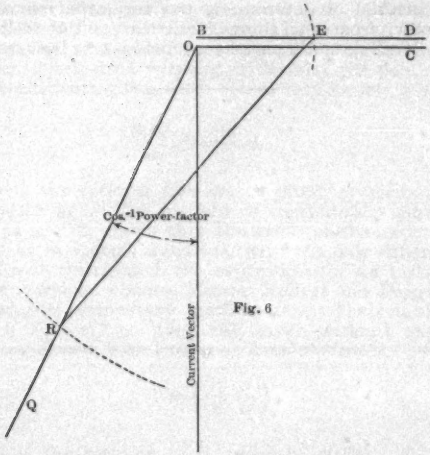


Fig. 6

As an illustration of the method, the regulation curve at zero power-factor for 20 amperes has been calculated for machine No. 3, see Fig. 4. The line $C\,A$ corresponds to 30 amperes, so for 20 amperes point H is located 2/3 of the way between C and A. The triangle is then moved and the point H describes the desired curve. The accuracy of this method for power-factors other than zero is somewhat questionable. The regulation curve for I/x amperes at zero power-factor should first be determined, and from this, if desired, the regulation at any other power-factor can be calculated by the following method.

Draw $B\,D$, Fig. 6, parallel to $O\,C$ a distance from it equal to the resistance drop. Lay off $O\,I$ the current axis, normal to

$O\,C$ and draw a line $O\,Q$ making with $O\,I$ an angle whose cosine is the power-factor for which we desire the regulation. For any excitation such as $A\,H$, Fig. 2, measure the drop $d\,a$, and using it as a radius strike an arc with O as a center, cutting $B\,D$ at E. Now with E as a center strike an arc equal to the no-load pressure $H\,d$, Fig. 2. This cuts $O\,Q$ at R. The length $O\,R$ is the terminal pressure for the excitation $A\,H$. This process is repeated for a number of points and a curve drawn through them. The work is greatly simplified if the same scale is adopted in Fig. 6 as that used in Fig. 2.

Having already obtained the regulation at zero power-factor and 20 amperes for machine No. 3, the regulation for 85% power-factor has been calculated by the method just described.

For a method of determining the regulation curve at zero power-factor, from the short-circuit curve, the reader is referred to Mr. Behrend's paper read before the INSTITUTE, May 19, 1903.

MEETING AT PITTSBURG, MAY 5, 1904.

DISCUSSION ON "CONTRIBUTION TO THEORY OF THE REGULATION OF ALTERNATORS."

V. KARAPETOFF:—The paper under discussion gives a complete method for the predetermination of characteristics of an alternator from its design. Three elements causing drop of pressure (beside ohmic drop) are taken into consideration: armature demagnetizing action, armature distorting ampere-turns, and armature self-induction. As these three causes are more or less independent of each other, they can be discussed separately.

1. *Armature Demagnetizing Ampere-Turns.*—The table given on page 190 of the paper by Messrs. Hobart and Punga gives in the first line demagnetizing ampere-turns for different ratios of pole-arc: pitch for a winding of one slot per pole. The numerical coefficients given there check very closely with the old formula:

$$\frac{0.57}{m} Sin \frac{\pi}{2} m$$

where m is the ratio of pole-arc to pitch, given by G. Kapp several years ago. The method of computation given in Appendix, page 212, shows that the same mathematical method was used as in Kapp's dynamos, with the only difference that Kapp directly integrated the expression for an instantaneous armature reaction, whereas Messrs. Hobart and Punga selected a long way of elementary mathematics. Their table for the "Breadth Factor." on page 191, given without explanation, checks very closely with Professor Arnold's factor,

$$Sin\left(\frac{\pi}{2}\frac{c}{a}\right),$$

where $\frac{c}{a}$ is the ratio of (coil breadth: pitch). As the table presupposes a distributed winding, the above factor must be integrated along one side of the coil, which gives

$$\frac{2a}{\pi(a-c)} Cos\left(\frac{\pi}{2}\frac{c}{a}\right)$$

and this last expression gives precisely the same results as the above table. If, however, the winding is distributed in but two or three slots per pole and phase, it seems more advisable to calculate directly the coefficient for each of the coils. The authors do not bring anything new into the method of determining armature demagnetizing action and use an already established and accepted theory.

2. *Armature Distorting Ampere-Turns.*—The authors make two assumptions to arrive at their results; namely, that at every instant the distorted flux acts as if it were concentrated in its center of gravity, and that the whole distortion corresponds to the average position of the center of gravity for an alternation. Once these assumptions are admitted, the results given in the second line of the table on page 190 are correct. But the assumption that a non-uniformly distributed flux can be concentrated in its center of gravity does not seem to be legitimate in this case. The authors begin with the distribution of the flux at a certain moment of time (Fig. 5 on page 189), and this is perfectly right. Now, if the distribution is known at any moment, the average distribution can only be found in a correct way by properly integrating the corresponding function, which expresses this distribution over a complete cycle, and not by making a new assumption. Once the problem is definite, every new assumption is superfluous, and therefore it can either be deduced from the data of the problem, in which case it is not necessary, or it contradicts these data and so leads to wrong results. If the authors would have followed the above-mentioned way, beginning with Fig. 5, they would have arrived at Guilbert's formula.

From a practical standpoint it is important to note that Guilbert's formula gives higher values for distorting ampere-turns than the method proposed in the paper under discussion.

3. *Armature Self-Induction.*—The authors do not establish any new data for the influence of self-induction, and they agree that with our present knowledge only a rough approximation in this respect is possible. They cite a formula for self-induction of open slots, based on calculation of the permeance of the paths for stray lines of force. For half-closed slots used in this country the corresponding formula is more complicated.

For free length of the coil they assume from 0.4 to 0.8 lines of force per centimeter of length. This is based on the following method:

Free ends of coils are supposed to have a semicircular shape; Professor Perry has given an approximate formula for self-induction of a flat circular coil without iron. The authors apply this formula to their case, forgetting that self-induction of a semicircle is by no means equal to half the self-induction of a complete circle. Besides, the proximity of the iron completely changes the conditions under which the formula has been deduced; moreover, usually the ends of the coils are not semicircular, and we do not know how far a change in shape affects the self-induction. Thus, the above data, 0.4 to 0.8 lines of force, seem to have no sufficient justification. The question of mutual induction of the phases is not mentioned at all in the paper under discussion.

Concerning an experimental verification of their method, the authors give results of short-circuit tests on 18 different

alternators, most of which check very well with their formulas. But it must be borne in mind that on short circuit the current is lagging almost 90° behind the e.m.f., so that there is no armature distorting action, only demagnetizing ampere-turns, for which the authors use the commonly-established, generally-accepted theory, which thus seems to get a new verification. As armature self-induction has only subordinate action in well-designed modern machines, the above results can hardly be considered as sufficient for accepting the method of calculation of self-induction proposed by the authors. This is the more true, as they do not take into account the mutual induction of the phases, which according to the data recently published by Professor Niethammer, in certain cases can almost double the effect of self-induction.

Of course, the authors give in their paper a complete verification of their method of calculation on a machine, including tests of high power-factors, where distorting action comes more into prominence; but on the other hand, Mr. Guilbert also verified his formula on a number of alternators which had been tested at the last Paris Exposition; so that so far the question remains undecided.

Messrs. Hobart and Punga certainly deserve our grateful acknowledgments for publishing a complete method with numerical applications. They bring it forth in a popular form, and every simplification of theory which makes it easier for practical application promotes a better design; at the same time it gives more opportunity for verification of the theory itself and separates its sound principles from mere hypothetical assumptions.

MEETING AT CHICAGO, APRIL 26, 1904.

Discussion on "European Practice in the Construction and Operation of High-Pressure Transmission Lines and Insulators."

W. A. Blanck:—The comparative figures given by Mr. Semenza for the cost of wood and iron pole-line construction include an item for right-of-way. It is considered necessary here, for good practice, to secure a full right-of-way for the pole line, and not separate patches of ground for each pole, in order to enable easy access to the line for inspection. Generally speaking, highways are selected for transmission lines here so that easy access may be secured with the least expenditure for right-of-way.

The conditions for right-of-way are then the same for both wood and iron poles. The following table gives comparative prices for conditions here:

Wood Pole.

53 wooden poles, 35 ft. with cross-arms and pins, $6	$318.00
Erection, $1.20	63.60
3 by 53 insulators, $1.50	238.50
	$620.10

Iron Pole.

9 steel towers with cross-arms and pins, 45 ft., $60	$540.00
Assembling and erection, $7	63.00
3 by 9 insulators, $1.50	40.50
	$643.50

Discussion on "The Conductivity of the Atmosphere at High Voltages."

C. E. Freeman:—Professor Ryan's paper raises some very interesting questions in connection with high-pressure transmission systems, and all apparatus and materials pertaining thereto. There is a feature connected with the experiments upon which the deductions of the paper are based that is of especial interest. The speaker refers particularly to the method of measuring the voltage corresponding to the various conditions of brush discharge.

During the past year or so the speaker has had considerable experience in this, and has discovered, among other things, a most imposing array of difficulties. For example, in determining the sparking distance between needle points, it is very difficult to obtain consistent results; in fact with certain methods of operation it is practically impossible. If the needle points are fixed in position, and the pressure gradually raised until sparking occurs, data will be obtained which present decidedly irregular features due to the fact that even with the best regulation of pressure it is difficult

to prevent its being raised or lowered by successive steps. Furthermore, the time during which the potential difference is applied materially affects conditions, as it charges the atmosphere if the surrounding space is enclosed as it should be, and causes any foreign particles to produce conducting chains between the points, produces charges in the points themselves, etc.

The other method is to fix the pressure and then gradually reduce the gap until either the brush discharge or the spark, whichever one is sought, occurs. This latter method gives fairly consistent results. However, the character of the needle points imposes a most important operating condition. In order that this may remain constant it is necessary to change needles after each discharge, which, of course, results in different points being used for subsequent tests, the variation depending upon those which occur in the manufacture of commercial needles, which are most commonly used in this connection. Furthermore, the shape of the e.m.f. wave, having a given effective value, determines the breaking-down point of the dielectric under test. It is sometimes a question as to whether this shape is the same for the various conditions and operations under which the tests are being conducted, since the wave induced in the high-pressure winding is not necessarily the one operating at the terminals of the transformer.

The other method of measuring the pressure over the spark-gap is to assume the ratio of transformation, or determine it for some low value, and assume that it remains the same throughout the range of operation of the transformer. Such a method is wholly unreliable in nearly every case, since in transformers of this character the excessive insulation required results in very appreciable magnetic leakage in the transformer. Under such circumstances one of Professor Ryan's problems in electrical engineering due to the conductivity of the atmosphere manifests itself. For the higher pressures the inevitable brush discharge from the windings of the secondary causes the transformer to load up, and the ratio of transformation is by no means what it was under the unloaded condition which existed when the ratio was determined or assumed from the relation of the windings. We have at Armour Institute a 25-kw., 150 000-volt transformer of the core type. In order to test this feature the pressures of the primary and secondary coils were measured simultaneously. In order to do this something like 10 wattmeter multipliers were placed in series with a Weston voltmeter, and the combination connected across the high-pressure side of the transformer. Upon increasing the pressure of the transformer another of Professor Ryan's problems presented itself. At the higher pressures the brush discharge from the windings of the voltmeter so seriously disturbed its operation that at something like 10 000 volts potential difference of the high-

pressure side the indications of the instrument were practically useless. A Thompson voltmeter of the inclined-coil type was substituted and in this way this particular difficulty was removed. However, the result of the experiment showed that the ratio of the e.m.f. was by no means constant, nor did it follow any definite law, owing to the variation in those conditions which affect brush discharge.

A most important point emphasized by Professor Ryan is that of the relation of the dielectric strength of the air to the barometric pressure. From his most recent investigations it would appear that this strength approximates 160 000 volts per inch, at 200 pounds pressure. This is about four times the dielectric strength of ordinary transformer oil, as we have found it by tests in our laboratories. From this it would appear that Professor Ryan's suggestion that compressed air or carbon-dioxid would form a most desirable substitute for oil is a good one, provided means could be had for maintaining such a pressure. For large transformers there seems to be no reason why this might not be done.

Professor Ryan's paper contains many suggestions throughout, and constitutes a distinct and valuable step toward the final evolution of high-pressure apparatus and transmission systems in general.

MEETING AT CHICAGO, MARCH 29, 1904.

Discussion on "The Relative Fire-Risk of Oil- and Air-Blast Transformers."

James Lyman:—The following features should determine the selection of transformers, as well as other electric apparatus:

1. Reliability of service, including capacity for all probable overload conditions of parctice.

2. Efficiency, regulation, the low rise in temperature under the various operating conditions.

3. Safety against personal danger to operators and safety against fire-risk, either from internal or external cause.

4. Compactness, simplicity of design, easy access to parts, and general cleanliness.

In small sizes the external surface of well-designed transformers is ample to radiate the heat due to copper and iron losses. The radiating surface per kilowatt, however, rapidly diminishes as the capacity increases, and in large sizes, from 1000 kw. up, it becomes absolutely necessary to carry off the heat by some circulating fluid, such as air, blown directly through the coils and the iron core, or water circulating in a coil of pipes suspended in the oil. While in transformers from 50 to 300-kw. capacity, it is perfectly practicable to design them of the self-cooling oil type, it is frequently more desirable to have them cooled from some entirely external source, such as by air-blast or water, as they can then be installed in a limited space where proper surface radiation cannot normally be obtained. The air-blast transformer has the advantage over the oil- or water-cooled type in being pretty nearly fire-proof. The insulation on the winding is the only combustible material in its construction, and this amount is comparatively small. Burn-outs in properly designed air-blast transformers are exceedingly rare, due to the fact that a comparatively low temperature can be maintained even under heavy overloads by varying the air-blast. The power required for driving the blowers is generally from 0.1 to 0.3% of the rating of the transformers, according to their sizes, so that the power required need not be considered in the efficiency of the transformers. In cases where burn-outs have occurred in air-blast transformers the writer does not know of an instance where the fire has extended beyond the damaged transformer, the shell of the air-blast transformer acting as a good fire-proof casing, and in case of external fire the air-blast transformer is seldom seriously damaged. When properly designed for thorough circulation of oil through the core and around the coils, and with properly-designed tanks, oil-cooled and water-cooled transformers should not offer serious fire-risks. The speaker believes that within the limiting pressure for which air-blast transformers can be used they are decidedly preferable to the oil

cooled. They are clean, compact, thoroughly reliable, and fully equal in efficiency and other characteristics, and, if anything, capable of greater overload abuse than the oil type. Above 30 000 volts the oil-cooled and water oil-cooled transformers must be used.

W. A. BLANCK:—In regard to the two types of transformers for transmission plants mentioned in Mr. Rice's paper, it is the speaker's opinion that a pressure of 30 000 volts forms the upper limit for the air-blast and the lower limit for the water-cooled oil transformer.

If the transformers be installed in the power-house and not separated from the engine-room by a fire-proof wall, the speaker is in favor of air-blast transformers on account of smaller first cost, convenience in securing proper attendance, and the considerably smaller fire-risk due to the small quantity of inflammable material.

If conditions call for a separate transformer house without special attendance, the speaker is in favor of water-cooled oil-immersed transformers set over suitable trenches so that any overflowing oil would be properly discharged outside of the building. The principal trouble encountered so far in oil transformers seems to arise from external sources, such as arcing switches and lightning-arresters mounted on wooden frames near the transformers. To overcome these fire-risks it will be necessary to use oil switches in brick compartments and to install all wiring on insulators carried by iron supports. Moreover the most essential requirement is to make the transformer house completely fireproof.

If for any reason self-cooled oil transformers are installed, the cases, if made of corrugated iron, should be strong enough to withstand external heat and should also be set over a suitable trench to discharge any overflowing oil. A fireproof housing is also greatly to be desired.

P. JUNKERSFELD:—One advantage of the oil-cooled type would appear particularly in those instances where large currents are taken from transformers for synchronous converters, at comparatively low pressure. Connections of sufficient current carrying capacity for 1000 kw. at 160 volts, would be difficult to bring into the top of an oil-cooled transformer.

Under such circumstances the air-blast type would have the advantage of making possible a shorter and more satisfactory heavy copper connection between transformer and synchronous converter.

G. N. EASTMAN:—He asks if any one has ever seen an oil-cooled transformer burn up; that is, the oil actually take fire and burn.

D. W. ROPER:—A case of that kind occurred in the East some time ago. A large single-phase, low-pressure transformer had the two sides of the secondary circuit brought out through different holes in the iron case. The hysteresis loss

in the iron produced enough heat to start a flame at one end, but the transformer did not burn up. The circuit was opened and the blaze was smothered.

In another case at the same plant an oil-cooled transformer of an early type was cooled by means of a water coil, in a tank removed from the transformer. An electric arc in the chamber in which the transformer piping was located burnt a hole in the pipe, which led from the transformer to the oil-tank. There was no check-valve in the pipe, and the arc set fire to the oil. The blaze continued until all the oil in the tank was consumed. This took some time, and in the meantime the switchboard operator tried to pull switches in the endeavor to put out the arc. Long before the fire stopped every switch in the plant was open. Those are two cases where fire occurred without destruction to the transformers.

G. H. LUKES:—If a device for smothering a fire in air-blast transformers is desired, use might be made of carbonic acid gas, which is easy to obtain. In case of a fire in an air-blast transformer, the air could be shut off and the carbonic acid gas turned on, when the fire would be quickly put out.

DISCUSSION ON "GROUP-SWITCHES IN LARGE POWER-PLANTS."

W. G. CARLTON:—In laying out a distributing system for high-pressure work simplicity should be aimed at in the switching arrangements at both the generating and receiving ends of the lines and also in the way of avoiding taps on the lines as far as possible. If the system is of any size conveniences for testing should be provided so that no unnecessary time will be lost in starting up the system after a shutdown, and also so that in case of trouble on a line, the latter can be easily and quickly tested without interfering with the operation of the rest of the system and without danger to the persons making the test. This matter is frequently lost sight of in the design of a station and the men who must operate it are placed at a disadvantage.

Oil-switches on high-pressure lines are commonly provided either with a straight overload tripping attachment, with an overload time-limit element or with no overload at all. If it is necessary to use any overload device, and it frequently is, it should have a time element depending on the load. To illustrate: if the normal maximum is 300 amperes, the overload should be set so that it would hold 450 amperes for three seconds, but would open instantly on 700 amperes. These figures are used for illustration and would vary with conditions.

The straight time-limit device is all right in case of an overload, but if this overload approaches short-circuit conditions, the switch will not open before the overload has dropped the pressure on the system sufficiently to cause synchronous apparatus to drop out of step. This has caused the abandonment

of straight time-element overload devices in the care of one station.

Underground high-pressure transmission lines should be carefully protected in manholes, both to provide against fire spreading from one cable to another and also to confine the arc in case a cable burns out. In the case of an unconfined arc if the system is of any size, excessive pressures are likely to be set up due to resonance, and the insulation of other cables and apparatus is likely to be broken down. Various forms of protection have been used. One of the best is split vitrified clay tile, using 45-degree elbows for the bends in the cable. When carefully installed this gives practically a continuous conduit line through the manhole. On long lines the lead sheaths of transmission lines should be broken at suitable intervals to prevent the flow of stray currents.

P. JUNKERSFELD:—In connection with Mr. Stillwell's paper, he would like to emphasize the fact that it is difficult to discuss this problem without referring to a particular case. Mr.

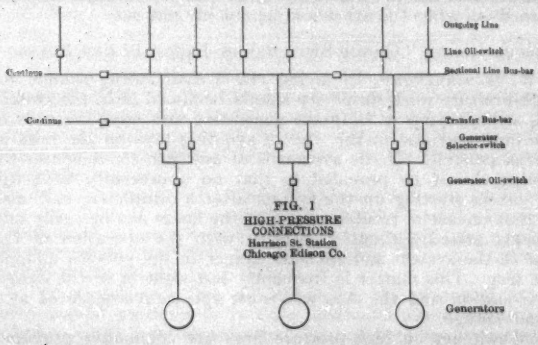


FIG. 1
HIGH-PRESSURE CONNECTIONS
Harrison St. Station
Chicago Edison Co.

Stillwell selected the case of a large power-house for street-railway systems. The conditions were known; that is, the load was pretty well known in advance, and the location of the sub-stations and the arrangement of the system could be figured out quite closely in advance. It was a conversion from steam to electric motors in the case of the Manhattan system and with the road in operation they could determine readily the load on transmission system. Likewise with the Metropolitan.

In a central-station system engaged in the lighting and power business, for instance, the conditions are somewhat different. It is not only a problem of designing the switching apparatus for conditions as they then appear, but also of meeting the conditions that arise in a rapidly-growing system.

Due consideration must be given to the percentage of total investment involved in different parts of the system. For instance, an additional investment in switches would often be small compared to an additional investment in lines. Therefore, while the number of long lines and the number of generating units are comparatively few, it will very often pay to introduce more flexibility in oil-switches and bus-bars.

To illustrate, in one of the Chicago stations, which is developed to its ultimate capacity, the high-pressure switching apparatus was entirely rearranged and overhauled during this last year. In that case the problem was not difficult and somewhat similar to that cited by Mr. Stillwell. The solution, however, was slightly different. Instead of the group-switch arrangement, a sectionalized bus-bar scheme was used as shown in Fig. 1. This line bus-bar is sectionalized in such a way that each generator may be made to supply its own section independently if desired. The transfer bus-bar can be divided into two sections only. Each generator has two selector-switches by means of which it can be connected either to its

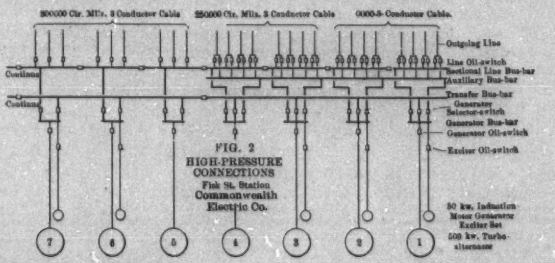


FIG. 2
HIGH-PRESSURE CONNECTIONS
Fisk St. Station
Commonwealth Electric Co.

own section of the line bus-bar or to the auxiliary bus-bar. With the generator-switch open and the two generator selector-switches closed, we also have a tie between a section of the line bus-bar and the auxiliary bus-bar. While each line has only one switch, there would, in case of trouble on line, always be two switches in series as the tie-switch would be used to cut off the section having trouble, in case the line-switch failed. This case is the Harrison Street Station of the Chicago Edison Company. The conditions were fairly well known when the overhauling was done, and the general design was, therefore, a comparatively simple matter.

In another case, the Fisk Street Station of the Commonwealth Electric Company, it was somewhat different. The scheme adopted is a little more complicated, at least it will be during the earlier development of the station. As the station grows larger, any one generator or line going out of service is a smaller percentage of the total and will not cripple

the system so seriously as in the first few years. The scheme is similar to the one previously outlined and shown in Fig. 1, except that there is an additional bus-bar introduced.

As shown in Fig. 2, there is a sectionalized line bus-bar, a transfer bus-bar and a third bus-bar known as an auxiliary bus-bar. In this case, there are three instead of two generator selector switches, and two instead of one line switch. One or more lines can be connected to the transfer bus-bar only through the medium of the generator selector switches and which under that condition perform the function of so-called group-switches. The installation of selector switches on each line and of the auxiliary bus-bar introduces a little more complication than the scheme shown previously, but the total number of switches is not greater than used in most high-pressure stations, having same size of generators and number of lines. Ultimately it is hoped to have simply the sectionalized line bus-bar and the one transfer bus-bar similar to the scheme shown in Fig. 1.

W. A. BLANCK:—Mr. Carlton's remarks in regard to time-limit devices in connection with high-pressure oil switches are very interesting, but disappointing to learn that these devices in which so much hope has been placed for the satisfactory operation of a high-pressure distributing system have been discarded. Why has this been done?

W. G. CARLTON:—In regard to the straight time-limit switch, a number of cases of trouble occurred, such as a short circuit on an underground line. If there is a time-limit switch on that line and the time limit is held on and will not allow the switch to open, the short circuit will work back and affect the whole bus-bar with which the line is connected, and, as a rule, will shut down everything running on that bus-bar. There have been a few cases of trouble on underground lines, not exactly in the nature of short circuits, possibly a ground, or something which would cause a good heavy overload and when the time limit has not been on, the switch has opened and cut out the line; when it has been, it has shut down everything on the bus-bar.

W. A. BLANCK:—Could not that difficulty be overcome by the proper setting of the time-limit devices, for instance the feeder-switches for two seconds and the generator-switches for four or six seconds?

G. N. EASTMAN:—The trouble with setting the time-limit switch for any given predetermined time is increased by the size of the system and the manner in which the lines are run. Conditions will arise in almost any system where there will be time-limit devices on lines which normally are not in series but under conditions of short circuit will be fed in series. The result is that other circuits are interrupted which have time-limit devices on them and always will be interrupted unless on that circuit on which the short circuit occurs, the time limit is set so that it operates before all others. One

can readily conceive how impossible it will be in a large system to vary the time so that these different time-element devices would be caused to operate for the location at which there is a short circuit.

P. JUNKERSFELD:—It seems that the original time-limit device was developed when the high-pressure system on which it was used was comparatively small and had comparatively few lines or branches. As the systems grow much larger, particularly in the cases cited by Mr. Carlton and Mr. Eastman, the straight time-limit relay is satisfactory for overload, but it is unsatisfactory for serious trouble on cables. Before such a time limit operates a good many things happen and it is necessary to have a device which will open very quickly and positively.

W. G. CARLTON:—In the matter of the time limit, if the time is at all appreciable, before that time has elapsed with a heavy short circuit, unless there is a very large amount of power on the bus-bar, the pressure on that bus-bar will drop sufficiently so that synchronous apparatus will all be stopped. That is one of the serious objections to a time-limit device.

DISCUSSION ON "OIL-SWITCHES FOR HIGH PRESSURES."

W. A. BLANCK:—The superiority of oil switches over air-break switches for high-pressure work, in so far as it relates to reliability of operation and line disturbance, is very well recognized, but still there are many cases where the much-abused air circuit-breaker in the form of a fuse breaking under oil or a lead fuse in connection with a spring-operated lever is the only device suitable to be installed.

In the case of a high-pressure transmission line passing a mining district, where the customers are usually widely scattered over the territory, and sub-stations with static transformers of less than 100 kw. capacity are often required, it is evident that an automatic oil circuit-breaker in a brick compartment would involve nearly double the investment of the transformer.

But as a matter of fact the high-pressure tap to the transmission line will be interrupted only in case of a breakdown of the transformers, since all secondary shorts or overloads are limited by properly dimensioned secondary fuses, so that the action of the air circuit-breaker, installed in connection with a set of disconnecting switches, is only called for in utmost emergency.

JAMES LYMAN:—In most cases the source of current supply for operating oil switches is a storage-battery, and wherever it is used it has proved a very reliable source. It is very seldom that an automatically operated oil switch fails.

P. JUNKERSFELD:—He believes that although switches are carefully built and located in the station, but little thought is given to the arrangement of the connections. This should not be the case.

DISCUSSION ON "TERMINALS AND BUSHINGS FOR HIGH-PRESSURE TRANSFORMERS."

W. G. CARLTON:—The speaker desired to know if any one present could state whether or not there are any 80 000-volt lines in operation.

E. O. SESSIONS:—In California the lines are operated from 45 000 to 60 000 volts, depending upon the reactance in the line.

P. JUNKERSFELD:—In a very large proportion of high-pressure work oil-switches play rather an important part. One question of importance is the building of suitable doors for oil switches. The question has been discussed in different parts of the country as to what is the best and most satisfactory door for an oil switch compartment. The glass door and wire glass door can readily be seen through for inspection purposes. While with the iron door or with the Alberene or slate slab you cannot readily inspect, and are liable to use the switch when it is not in order. Alberene slabs and iron doors can not be so easily and safely removed as glass ones and consequently the switches are not so frequently inspected as they should be.

G. N. EASTMAN:—One instance might be cited where a company operating in Chicago had a solid door and for some reason the oil suddenly disappeared from the oil wells. There was only a slight indication of this from the oil on the floor outside. The switch, however, operated satisfactorily on closing, but not so well on opening the circuit. When the doors were removed it was seen that there was considerable oil inside the switch.

W. G. CARLTON:—The speaker thinks the amount of wood in the frame of the door is not enough to cause much fire. There is practically an equal amount of inflammable material close to the switch in the insulation of the leads. In operating a number of lines on one bus-bar, when several switches open up due to trouble, it is not always possible to tell on which line the trouble is. If the oil switch opens up a line on which there is a short circuit, some oil will generally be thrown from the switch. With a glass door the attendant can see where oil has been thrown out of the switch and thus save time in locating the trouble, as has been proved by experience in a number of cases. There is the possible objection of breaking the glass, but there is not much fire-risk with the amount of wood available.

I. E. BROOKE:—In the construction of some oil switches it seems as if an iron door comes rather close to the live copper, and that the liability of grounding on the iron door would more than overbalance the objection to the fire element on a wooden door.

MR. THOMAS:—The speaker believes it has been the practice to ground the framework of the oil switch as well as the door. He approves of it and considers that everything in the shape of framework on a switchboard should be grounded.

P. JUNKERSFELD:—One point particularly has been brought out in connection with oil switches, and that is that they need a great deal of attention. A switch is looked upon as something which can be operated occasionally and then left alone; but that is not the case with an oil switch. It must have frequent and good inspection, and in order to get good inspection it must be arranged so that the operator may easily see its condition. One of the speakers has made the suggestion to have an iron door which would open outward and downward. Why does he say you get better inspection when a man opens an iron door than when he looks through a glass door?

E. O. SESSIONS:—The speaker has used wooden doors with glass windows for the switch cells, but they were replaced by iron doors, about eight and a half inches away from switch tank with a two-inch air-space all around the door, on account of the destruction of the wooden ones.

P. JUNKERSFELD:—Glass doors of heavy plate glass in three sections which will enable every part of the switch from the bottom terminal to be seen have been in service for some time.

W. G. CARLTON:—In the case Mr. Sessions mentioned of the glass door being blown off, why would not the same thing happen to an iron door? also trouble has been caused by switches grounding to an iron door.

E. O. SESSIONS:—With wooden doors the case was fitted tight, while about the iron doors there was left a two-inch space. With glass doors after one blow out of the switch, the glass would be so obscured that it would be impossible to note what happened without opening the door, but arranging the iron door so that it lacks two inches of closing will permit the inspection of the switch.

R. F. SCHUCHARDT:—To illustrate the point brought out by Mr. Brooke, the speaker cited the following case: An oil-switch had opened on a very heavy overload and some of the porcelain posts were so badly broken that one of the oil wells fell forward. After the switch was opened the lower part connected to the oil wells was still alive and if this well had fallen against an iron door thoroughly grounded, the resultant short circuit would certainly have caused great damage. With a wooden door with a glass front no live parts could come in contact with metal.

E. O. SESSIONS:—In the Waterside Edison station in New York all the doors are made of soapstone, or Alberene, as it is called, and are fitted in close against the brickwork.

EDW. SCHILDHAUER:—If Mr. Session's advice is followed to erect the door two inches from the brickwork, the fire-proof advantage of the iron door is *nil*. It would look rather odd to see a brick switch compartment lined with Alberene stone on three sides and equipped with an iron door on the fourth or front side, while the distance from the oil vessel to the door is the same as to the Alberene. If an oil vessel bursts with

enough generator capacity back of it, the speaker believes that there will be in most cases very little left of the iron door.

P. JUNKERSFELD:—The large companies in Chicago have had some oil switches in operation for a number of years; in fact, some of the first hundred switches that were made for the Metropolitan station in New York, which was the first extensive installation of the compartment-type of switch, were shipped to Chicago. The first had the asbestos and iron doors, then followed Alberene doors, and more recently the advantages of the glass door appeared. One or two experiences brought out very forcibly that it was desirable to have a glass door and at the same time a fire-proof door. That, of course, meant a metal casing. After that, however, it was realized, as Mr. Carlton pointed out, that what little wood is introduced does not seriously diminish the fire-proof character of the door and does not increase the danger. The fire-proof barriers between the phases are really depended upon to prevent trouble. It is not often that the switches are gotten close enough so that anything thrown out at the front would be a serious matter.

G. N. EASTMAN:—Some five years ago, when the question first came up about using oil switches in preference to air switches, he made some tests to determine what the relative rise in pressure in the cable would be upon opening the circuit. He found that in a three conductor No. 00 cable three miles in length, the changing current was great enough so that upon opening the circuit with an air switch, the arc could be gradually drawn up, and an increase in potential of 50% " noted by a static voltmeter " could be obtained. If the switch was opened quickly, using a single break in the oil, no increase in pressure could be noted. Drawing the arc out in the oil a rise of from 10 to 15% was obtained. By connecting four breaks in series in oil it was practically impossible, under any conditions, to obtain a rise in pressure.

The speaker believes that upon opening a short circuit the tendency of the arc to hold would be reduced by having breaks in series. With some conditions, it is only by holding the arc—" the arc acting as an interrupter "—that you obtain a rise in pressure. The rise will be more severe with a short circuit under certain conditions than with only the charging current.

MEETING AT PHILADELPHIA, MAY 9, 1904.

DISCUSSION ON "THE USE OF GROUP-SWITCHES IN LARGE POWER-PLANTS."

H. F. SANVILLE:—For an important installation, which must consist of a large number of feeders all of considerable energy capacity, the extra expense of the additional switches is warranted. For such systems as the Manhattan, New York Edison, Metropolitan, and Rapid Transit in New York, it is almost, if not quite, necessary to adopt the group arrangement. In these systems each group runs to a separate sub-station, so when a station is shut down it is possible to test the mechanical operation of the mechanism from the controlling panel without any interference with service and without opening the lever disconnecting switches.

The necessity of the group-switch in series with the feeder-switch was a development of the uncertain operation of oil-switches under emergency conditions. It has since been found, however, that the switches are extremely reliable and will rupture circuits carrying almost unlimited amounts of energy.

The high rupturing capacity of the switches makes it desirable that the group-switch be made automatic only through a time-limit relay, which will allow a defective feeder to disconnect itself from the group bus-bar without necessarily shutting down the entire group.

By the proper arrangement of controlling switch circuits reduction of load can be readily made without the use of a group-switch and the load may also be transferred. In some installations a sectionalized ring bus-bar automatic switch has been used in place of group-switch.

DISCUSSION ON "OIL-SWITCHES FOR HIGH PRESSURES."

H. F. SANVILLE:—Recently a series of tests of oil switches were made including over 1000 records of currents from short-circuited alternators varying from two 300-kw. machines at 13 000 volts to a generator capacity of three 3750-kw. machines at 2200 volts, including also a number of tests at 75 000 volts. It is almost invariably the rule, as shown by the records, that the circuit opens at or near the zero of the wave, in almost every case the circuit opens on three consecutive zeros in the three phases; fewer than 10 exceptions to this were recorded; in the exceptional cases the current of one phase holds for one or two cycles beyond the first one to rupture.

It may be of interest to state the conditions of some of the short circuits which have been successfully opened by oil switches during the last few years.

1. Seven 5000-kw three-phase, 11 000-volt generators on the Manhattan System were connected to the bus-bar. A short circuit occurred within 300 feet of the station, the

automatic switches opening without difficulty. There were at this time some coincident cable breakdowns, due probably to the resonant effects set up by the enormous arc at the subway junction box where the short circuit occurred. Since that time a steel tape has been used at the cable connections to prevent a short circuit developing an air arc.

2. *New York Edison System.*—Seven 3500-kw. 6600-volt generators were on one bus-bar and four on a second. A connecting switch was accidentally thrown in with the bus-bars out of phase; the oil switch ruptured the circuit without causing any disturbance to the system.

3. *Niagara Falls.*—Five 5000-h.p. generators on the bus-bars stepping up through 25 000-h.p. transformer capacity to 22 000 volts on the Lockport feeder. A short circuit was made by a wire thrown across the transmission line and the circuit was successfully opened by the oil switch on the high-pressure side.

4. *Niagara Falls.*—In power house No. 2 of the Niagara Falls Power Co. two weeks ago, a short circuit developed on the 11 000-volt feeder running to the Canadian side with seven 5000-kw. generators on the bus-bar. The cables made a peculiar rattling sound from the movement of the insulators, but no damage was done the circuit being opened without any disturbance of the system by the oil-switch on the 2200-volt feeder to the transformer house.

5. Some time ago some short-circuit tests were made on the 33 000-volt system of the Aurora, Elgin, & Chicago Railway Co. These tests were made single phase and three phase at the main station and also at the Warrenville sub-station at the other end of the line. The circuits were opened without difficulty by the oil switches; then the switches were made double-break for opening the three-phase shorts instead of three breaks; *i.e.*, the middle leg of the switch was short circuited, but no difficulty was experienced in opening the circuits.

6. In another test a 2500-kw., 2200-volt alternator was excited to 2500 volts and stepped up to 75 000 volts by three 750-kw. transformers, giving a total transformer capacity of 2250 kw. The standard 60 000-volt oil switch operated as a single-break switch by cutting out one row of pots, opened three-phase short circuits without the slightest difficulty.

W. C. L. Eglin:—Most of the difficulties in the use of oil switches are not in the electrical but in the mechanical features. The clutches between the motor and the switch mechanism, and the devices to maintain the switch either in its open or closed position, have been responsible for most of the failures, necessitating frequent inspections and adjustments of these parts of the switch. Proper alignment of parts, rigid construction, and ample capacity in clutches, with stops arranged to hold positively the switch in an open or closed position are essential to the satisfactory operation of an oil-switch.

The care of the oil is very important. After the oil has been in use for some time, it will deteriorate, due to the operation of the switch and to the collection of foreign material in the oil. Care must be taken to prevent water from mixing with the oil; the oil should be completely changed at regular intervals, and means be provided to keep the oil clean. In one case of failure of an oil switch the current jumped a distance of half an inch in the oil, and punctured the fibre lining of the oil case. The oil was examined and there was found sediment of dirt and dust at the bottom of the oil tank. This switch had been cleaned within six months.

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS.

NEW YORK, May 17–18, 1904.

The 187th and annual meeting was held these dates at the Chemists' Club, New York.

MAY 17, 10:45 a.m. TO 1:00 p.m.

The following papers were read and discussed:

1. *Predetermination of Sparking in Direct-Current Machines*, by W. L. WATERS.
2. *Effect of Self-Induction on Railway Motor Commutation*, by E. H. ANDERSON.
3. *On the Calculation of Line Batteries*, by W. E. WINSHIP.

MAY 17, 8:30 p.m.

President Arnold called the meeting to order at 8.30 o'clock and said: "This is the 20th anniversary of the organization of our INSTITUTE, and I think we may all congratulate ourselves upon its accomplishments, its growth, and its present condition. The condition of the INSTITUTE as it now stands will best be shown by the reports of the various committees which we will hear digests of to-night."

The Secretary then announced the election of the following officers for the ensuing year:

President, J.W. Lieb, Jr.; Vice-presidents, W. E. Goldsborough, J. J. Carty, Samuel Reber; Managers, H. G. Stott, L. A. Ferguson, J. G. White, S. S. Wheeler; Treasurer, George A. Hamilton; Secretary, Ralph W. Pope.

The Secretary then presented to the INSTITUTE the report of the Board of Trustees.

THE PRESIDENT—The energies of your officers during the past year have been largely devoted to systematizing the work of the Board of Directors, and in carrying out the arrangements to take care of our foreign guests during the International Congress next September. This has taken a large part of the time of most every man connected with the work. The results of the methods inaugurated during the previous administrations and of our endeavors to carry them out during this administration are given in the report, which covers two administrations and represents the progress of the INSTITUTE irrespective of any individual officer. We are to be congratulated that the INSTI-

TUTE gets along so well. The indications are we shall continue to grow rapidly and solidly.

C. F. SCOTT:—Two years ago about this time I called at the Secretary's office, and in a conversation he suggested the establishment of local branches as a means of increasing the interest in our INSTITUTE. One of the things I thought needed to be done was to broaden and nationalize the work of the INSTITUTE. I had felt that in some way we must get the outside members into activity, and the suggestion of the Secretary has been the means of doing that. A committee on Local Organization was provided, and Mr. Rice was the chairman of the committee the first year. I have held the chairmanship the second year. Certain data have been collated and tabulated in connection with the several local organizations, showing the membership and other details. The membership in the local branches two years ago was 500, now it is 1068, a gain of something over 100 per cent. The students of the INSTITUTE in connection with Branches number 273. The total number of Branch meetings during the year was 274. The average attendance at these meetings, usually held once a month, runs all the way from five in one of the Branches up to 20, 50, and 100. There are four in which the average attendance was over 100. The aggregate average attendance is 1291. Seventy-nine original papers were presented.

Mr. Scott then read his report in detail. (See May, 1904, TRANSACTIONS.)

THE PRESIDENT:—I think we are to be congratulated on the work of the Branch meetings. I think we have accomplished considerable in the last year, simply in focusing the work of the Branches and in adopting by-laws. We succeeded at the last Directors' meeting in adopting some by-laws under which we can work. It involved a great deal of careful work on the part of the Chairman of the By-Laws Committee, who is our Secretary, and the other members of the committee.

Mr. C. W. Rice, chairman of the Building Fund Committee, made a brief report.

THE PRESIDENT:—I wish to call attention to the report of the Library Committee, which has been printed and is in your hands. It shows excellent work on the part of the committee.

The Secretary announced that 249 members had sent proxies, which, with the members present, made a regular quorum of the INSTITUTE.

SECRETARY POPE:—At the meeting of the Board of Directors this afternoon, the following 64 Associates were elected:

Name.	Residence.	Endorsers.
ADAM, FRED B.,	Secretary and Manager, Frank Adam Electric Co., 914 Pine St.; res. 2326 Albion Pl., St. Louis, Mo.	H. H. Humphrey. R. H. Moore. R. W. Pope.
BARCLAY, GEORGE,	New Zealand Volunteers, Palmerston, Otago, N. Z.	W. G. T. Goodman William Maver, Jr. R. W. Pope.

BATES, FRANCIS REED, Consulting Engineer, Bogart-Bates Co., 508 Pacific Block, Seattle, Wash.	K. G. Dunn. M. P. Randolph. A. A. Miller.
BECKETT, BERGIE BARRY, Student, Cornell University; res. 303 Eddy St., Ithaca, N. Y.	H. H. Norris. H. J. Ryan. G. S. Macomber.
BLIZARD, JOHN WALTER FREDERICK, Chief Draughtsman, Keystone Telephone Co.; res. 1717 Aberdeen St., Philadelphia, Pa.	J. W. Kelly, Jr. W. L. Hodges. R. W. Pope.
BRAMHALL, CHARLES A., Manager, Diehl Mfg. Co., 561 Broadway, New York City; res. Allendale, N. J.	Arthur Williams. F. E. Kinsman. R. W. Pope.
BROSIUS, JAMES SIMMS, Engineering apprentice, Westinghouse Electric Mfg. Co., Pittsburg; res. 753 South Ave., Wilkinsburg, Pa.	C. E. Downton. K. C. Randall. C. Renshaw.
BROWN, ALFRED EVELYN, Partner, Scott and Brown, Christchurch, New Zealand.	A. J. Hanson. William Maver, Jr. R. W. Pope.
BYLLESBY, HENRY MARISON, President, H. M. Byllesby and Co., New York Life Building, Chicago, Ill.	G. A. Damon. Samuel Insull. J. R. Lovejoy.
CURTIS, LEONARD E., Vice-president and Treasurer, Guanajauto Power and Electric Co., Giddings Building, Colorado Springs, Colo.	B. J. Arnold. William Stanley. C. F. Scott.
DEAN, GEORGE COOPER, Member of firm Johnston and Dean, 11 Pine St.; res. 823 West End Ave., New York City.	T. J. Johnston. C. A. Terry. R. W. Pope.
D'HUMY, FERNAND EMILE, District Electrician, Postal Telegraph Cable Co., 84 State St., Boston, Mass.	F. W. Jones. M. M. Davis. J. F. Skirrow.
DUNWOODY, HENRY H. C., Instructor, Commanding Signal Corps Post, Fort Myer, Va.	Samuel Reber. Philander Betts. Townsend Wolcott
EDWARDS, CHARLES GRIFFIN, Assistant Engineer, Electrical Commission of Baltimore City. City Hall, Baltimore, Md.	C. T. Hutchingson Hugh Pattison. A. J. Rowland.
EVELETH, CHARLES MIRICK, Assistant Electrician, American Telephone and Telegraph Co.; res. 44 Irving Pl., New York City.	G. M. Yorke. Cabot Stevens. R.T.Chetwood, Jr.
FRANCISCO, FERRIS LE ROY, Supervising Electrician, Consolidated Tobacco Co.'s Room 514, 111 5th Ave.; res. 60 W. 101st St., New York City.	S. L. Nicholson. E. C. Johns. G. F. Atwood.
FRIDENBURG, HENRY LESLIE, Secretary and Manager, Electric Utilities Co., Flatiron Building; res. 114 W. 126 St., New York City.	A. F. Ganz. D. S. Jacobus. R. W. Pope.
FRIES, JÔNS ELIAS, Engineering Department, New York Edison Co.; res. 12 W. 107 St., New York City.	E. B. Fahnestock. B. P. Wiltberger. Nicolai Aall.
GALE, FRANK HARVEY, Advertising Manager, General Electric Co., Schenectady, N. Y.	C. D. Haskins. C. W. Rice. G. F. Sever.
GILLILAND, CLARENCE REY, Correspondent, Westinghouse Electric and Mfg. Co., Pittsburg; res. 439 Rebecca Ave., Wilkinsburg, Pa.	C. F. Scott. H. R. Stuart. C. E. Downton.

GLENN, CHARLES SEWALL, Electrical Inspector, Baltimore and Ohio R.R., Newark, Ohio.	W. D. Young. Louis Duncan. W. L. Puffer.
GOEHST, J. HENRY, Construction Superintendent, Chicago Edison Co., 139 Adams St., res. 4613 Langley Ave., Chicago, Ill.	L. A. Ferguson. J. F. Gilchrist. B. J. Arnold.
GOLDSMITH, LEON, Westinghouse Electric and Mfg. Co., 1104 Harrison Building, Columbus, Ohio.	M. C. Hull. L. G. White. F. C. Caldwell.
HICKS, DE FOREST, Manager, Western Electric Co., 933 Market St.; res. The Clinton, 10th and Clinton Sts., Philadelphia, Pa.	G. S. Loutey. F. A. LaRoche. T. F. J. Maguire.
HOWELL, CECIL ASHBROOKE, Transformer Designing Engineer, Wagner Electric Mfg. Co., St. Louis, Mo.	W. A. Layman. B. A. Behrend. G. E. Wells.
HOWELL, GEORGE D., Engineer in charge, Lake Erie Traction Co.; res. 429 N. 33d St., Philadelphia, Pa.	H. F. Sanville. W. A. Smethurst. R. W. Pope.
HYMAN, WALLACE MUNROE, Assistant P. R. Moses; res. 11 E. 80 St., New York City.	P. R. Moses. G. F. Sever. A. A. Zucker.
JOSEPH, THEODORE HAROLD, Member of firm, E. J. Electric Installation Co.; res. 205 W. 138 St., New York City.	F. B. Crocker. Morton Arendt. Fitzhugh Townsend
KODJBANOFF, BASIL GEORGE, Illuminating Engineer, Benjamin Electric Mfg. Co.; res. 329 5th Ave., New York City.	C. E. Knox. C. O. Mailloux. W. D. Steele.
LAMME, WILLIAM FENNER, Construction Department, Westinghouse Electric and Mfg. Co., San Francisco, Cal.	C. F. Scott. P. M. Lincoln. B. G. Lamme.
LEA, EDWARD S., Sales Manager, DeLaval Steam Turbine Co., 74 Cortlandt St., New York City.	B. A. Behrend. L. E. Bogen. R. T. Lozier.
LEE, WILLIAM S. JR., Vice-president and Chief Engineer, Catawba Power Co., Rock Hill, S. C.	J. H. Finney. F. D. Sampson. W. B. Spellmire.
LOMBARD, PERCIVAL HALL, Salesman General Electric Co., 305 Crossley Building, San Francisco, Cal.	F. F. Barbour. C. R. Cross. E. B. Raymond.
LUDWIG, RUDOLF EMMANUEL, Electrical Engineer, Ludwig and Co., 513 Empire Building. Atlanta, Ga.	S. M. Conant. R. W. Pope. J. W. Little.
MANSFIELD, EDWARD STACEY, Edison Electric Illuminating Co., 70 State St., Boston, Mass.	J. W. Cowles. C. L. Edgar. W. L. Puffer.
MCKAY, MAURICE PARKER, Engineer, Westinghouse Church Kerr and Co., 10 Bridge St., res. 211 W. 69 St., New York City.	W. N. Smith. W. S. Valentine. I. J. Macomber.
MOODY, WILLIAM EDGAR, Draughtsman, American Elevator Co.; res. 166 W. 4th Ave., Columbus, Ohio.	W. K. Liggett. M. S. Browne. M. C. Hull.
MOORE, CLIFFORD THOMPSON, Electrician, U. S. Navy Yard, League Island; res. 4535 Pulaski Ave., Germantown, Philadelphia, Pa.	G. S. Loutey. F. A. LaRoche. T. F. J. Maguire.

MOUNTAIN, JOHN THEODORE, Load Despatcher, Chicago Edison Co., 139 Adams St.; res. 409 E. Huron St., Chicago, Ill.	W. L. Abbott. W. G. Carlton. P. Junkersfeld
MÜLLER, HENRY NIKOLA, Electrician, Allegheny County Light Co.; res. 235 Millvale Ave., Pittsburg, Pa.	N. C. McPherson. Harry Etheridge. Brabazon Rutherfoord.
NICHOLSON, LLOYD CARLTON, Instructor, University of Missouri, Columbia, Mo.	H. B. Shaw. H. C. Don Carlos. W. K. Freudenberger.
NORTON, WILLIAM JOHN, Agent, Federal Electric Co., 13 W. Lexington St.; res. 2438 Maryland Ave., Baltimore, Md.	Douglass Burnett. H. J. Ryan. Peter Junkersfeld.
NURIAN, KERSON, Superintendent of Construction, Main Switch Board, Mechanical and Electrical Dept., World's Fair, St. Louis. Mo.	M. C. Hunter. W. K. Dunlap. R. W. Pope.
OSTHOFF, OTTO EARNEST, Electrical Engineer, H. M. Byllesby and Co., 420 New York Life Building, Chicago, Ill.	L. A. Ferguson. G. A. Damon. R. W. Pope.
PETTIT, JAMES EDWARD, Chief Operator, Postal Telegraph Cable Co.; res. 145 Campbell Ave., Chicago, Ill.	F. W. Jones. M. M. Davis. J. F. Skirrow.
PIERSON, HENRY GREGORY, Member of firm, Foote, Pierson and Co., 82 Fulton St., New York City; res. 246 Turrell Ave., So. Orange, N. J.	M. M. Davis. F. W. Jones. W. B. Vansize.
POTTER, HERBERT STURGIS, Electrical Engineer and Contractor; res. 6 Trinity Pl., Boston, Mass.	J. W. Cowles. E. L. Caldwell. C. H. Herrick.
ROBERTS, GEORGE CLIFFORD, Electrical Engineer, Walker Electric Co.; res. 222 Paxon St., Philadelphia, Pa.	Max Friemark. C. H. Bedell. C. E. Bonine.
SCHNEIDER, CARL ALBERT, Student, Columbia University; res. Perth Amboy, N. J.	G. F. Sever. F. B. Crocker. Fitzhugh Townsend.
SCHULER, L., Electrical Engineer, Wagner Electric Mfg. Co., 2017 Locust St., St. Louis, Mo.	W. A. Layman. A. H. Timmerman R. W. Pope.
SCHWABACHER, FRANK, Student, Columbia University; res. 505 W. 124 St., New York City.	G. F. Sever. R. W. Pope. Morton Arendt.
SKOG, GUSTAF, EMANUEL Erecting Engineer, Westinghouse Electric Mfg. Co.; res. 325 Pitt St., Wilkinsburg, Pa.	O. A. Sandborgh. S. Q. Hayes. Erik Cronvall.
SLEMIN, HARRY C., Telephone Engineer, Stromberg Carlson, Telephone Mfg. Co.; res. 9 Cornell St., Rochester, N. Y.	Carl Kinsley. H. R. King. M. W. Zabel.
SMITH, ROBERT JAMES, Superintendent, Canadian Electric and Water Power Co., Ltd., Perth, Ont., Can.	C. H. Sharp. A. A. Dion. R. W. Pope.
STIMPSON, CLARENCE ARNEY, Chief Operator, Postal Telegraph Cable Co., 1326 Chestnut St.; res. 878 Highland Ave., Philadelphia, Pa.	F. W. Jones. M. M. Davis. J. F. Skirrow.

STRATTON, SAMUEL W., Director, National Bureau of Standards, Washington, D. C.	Elihu Thomson. W. D. Weaver. E. H. Mullen.
STRENG, LEWIS STARR, Assistant Engineer, Public Service Corporation of New Jersey, 207 Market St., Newark, N. J.	Dudley Farrand. Paul Spencer. W. L. Puffer.
THOMAS, STEPHEN A., Chief Electrical Inspector, Department of Education, 59 St. and Park Ave., New York City; res. 84 Harrison Ave., Port Richmond, S. I., N. Y.	Edward Durant. David Lowson. R. W. Pope.
WALLACE, JOHN EUGENE, Assistant Engineer, L. B. Stillwell, 2502 Park Row Building, New York City; res. 371 Macon St., Brooklyn, N. Y.	H. G. Stott. J. J. Mahony. A. D. Babson.
WEBER, FREDERICK CARL, Tester, General Electric Co.; res. 516 Smith St., Schenectady, N. Y.	D. C. Jackson. C. F. Burgess. F. P. Way.
WISWELL, OZRO N., Snoqualmie Falls and White River Power Co., Snoqualmie Falls, Wash.	John Harisberger. P. H. Knight. E. P. Pennebaker.
WOLLS, WILLIAM A., Chief Engineer, Peruna Drug Mfg. Co.; res. 147 Thurman St., Columbus, O.	Perry Okey. L. G. White. M. C. Hull.
WOODMANSEE, FAY, Electrical Engineer, Sargent and Lundy, Railway Exchange; res. 5405 Calumet Ave., Chicago, Ill.	A. D. Lundy. T. P. Gaylord. W. L. R. Emmet.
YOUNGBLOOD, FRANK JAMES, Special apprentice, British Westinghouse Electric and Mfg. Co.; res. 11 Derbyshire Lane, Stretford, Manchester, England.	A. F. Ganz. D. S. Jacobus. Gilbert North.

Total, 64.

The following paper was then read and discussed:

4. *Data and Tests on a* 10 000 *Cycle-per-Second Alternator*, by B. G. LAMME.

MAY 18, 10:30 a.m. TO 1:00 p.m.

The following papers were read and discussed:

5. *Notes on Fly-Wheels*, by H. H. BARNES, JR.
6. *The Single-Phase Induction Motor*, by W. S. FRANKLIN.
7. *Wave Form Variations of a Long-Distance Line*, by GEO. H. ROWE.

THE PRESIDENT:—Before closing the meeting, I take pleasure in announcing the receipt of substantial increases in our building fund since the statement made by the chairman of the committee at last night's session. Mr. Rice telephoned that a subscription of $1000 has been received by him from Mr. E. W. Rice, Jr., of Schenectady. Mr. Martin, of the committee, also telephones that he has received from Mr. Thomas A. Edison a subscription of $5000. The total fund, therefore, is now $54 000, and it would be unsafe to say what it will be when we hear from Mr. White, the other member of the Building Fund Committee.

DISCUSSION ON "PREDETERMINATION OF SPARKING IN DIRECT-CURRENT MACHINES" AND ON THE "EFFECT OF SELF-INDUCTION ON RAILWAY-MOTOR COMMUTATION."

W. L. WATERS:—In the last two or three years the formula presented in this paper has been checked up on a complete line of machines which has been designed and built in sizes from 2 to 1000 kw. As indicated above, the allowable value of the sparking constant was found to vary with the number of poles, and the output and the type of winding on the armature; but among machines which were directly comparable in these respects the formula gave quite good results and usually the sparking limits of the machines could be predicted to within about 10 per cent.

Occasionally, however, we would come across machines, which gave results which varied quite considerably from those predicted by the formula. This variation being in some cases as much as 40 per cent. No apparent explanation of some of these variations was found and they were considered merely as evidences of the fact that this sparking formula does not by any means take into account all the conditions which affect the sparking, so that though the formula gives in general good results it should be used with a certain amount of discretion.

E. R. DOUGLAS:—Referring to Mr. Waters' paper, the speaker wishes to discuss, not the inequality factor, but the fundamental part of the formula which concerns the self-induction of the coil itself. On page 358 we read:

"The self-induction of one conductor embedded in the slot equals $l\,k$, where l is the length of the core and k is a constant depending on the dimensions of the slot."

On the next page is a curve, showing the relation between k and the proportions of the slot. This formula makes the self-induction of the coil depend entirely on the flux within the slot itself, neglecting a system of flux which is much more important in causing self-induction. Fig. 1 shows an armature of which but two slots, a and b, are drawn. A coil $c\,d$ lies in those slots. The current in that coil sets up a certain flux surrounding the conductors of the coil. A part of the flux, it is true, goes directly across the slots above the coil and through the wire itself, as $e\,f$. This is what Mr. Waters has considered. But a further and larger portion of flux goes around in great sweeps g, which, if the armature were out of its magnet frame, would be uninterrupted to an indefinite distance. That portion of the inductance due to flux around the core may be greater than that due to flux within the slot. This was called to our attention in a paper entitled "Sparkless Reversal in Dynamos," by Mr. H. N. Allen, in the Journal of the British Institution of Electrical Engineers, in April, 1898.

Contrary to Mr. Waters' practice, Mr. Allen neglects the flux within the slot, but pays much attention to the flux around

the core. He assumes a very long drum armature, so that the ends do not come into consideration. In Fig. 2, let *a* and *b* represent cross sections of two long parallel conductors carrying currents in opposite directions. The lines of magnetic flux surrounding these conductors will be represented by the lines *c*, and the equipotential surfaces of this magnetic flux by the lines *d*. The sections of flux and equipotential surfaces form two systems of circles cutting each other orthogonally. It is not difficult to compute the flux due to such a system.

If the space within any equipotential surface, as *d'*, be filled with material of perfect permeance, the values of the flux will be doubled in amount irrespective of which equipotential surface be chosen. Allen's formula is based on this conception, but is not satisfactory when applied to the ordinary type of

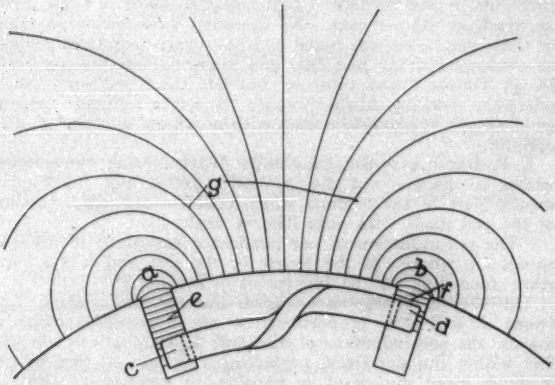


FIG. 1.

armature, because the ordinary armature is not a long cylinder, and the effect of the end connections is great.

A different conception was introduced in some work done by engineers of the Crocker-Wheeler Company. Instead of considering an infinitely long cylindrical core with two parallel conductors, a spherical core was assumed having a circular coil lying on it. Current circulating in the coil would set up a flux through the coil, spreading out in all directions.

The flux through a circular coil entirely surrounded by air is susceptible of calculation. If that coil be placed on a sphere of perfect permeability the flux will be increased, and it is also possible to calculate the increase. The flux around a circular coil on a spherical coil of high permeability may

therefore be known. Fig. 2 will also represent such a circular distribution, $a\ b$ being sections of the conductor of the circular coil, and $x\ y$ the axis. The surfaces of flux and of equipotential are very nearly spherical.

The ordinary armature coil has somewhat the shape of a regular hexagon. The inductance in air of a circular coil of the same enclosed area will not be very different from that of the hexagonal coil. The actual coil is laid on a core of high permeability; that core, it is true, is not spherical and does not touch the coil all around, but the inductance calculated for the circular coil and spherical core comes very near to the actual inductance. Of course it does not take into ac-

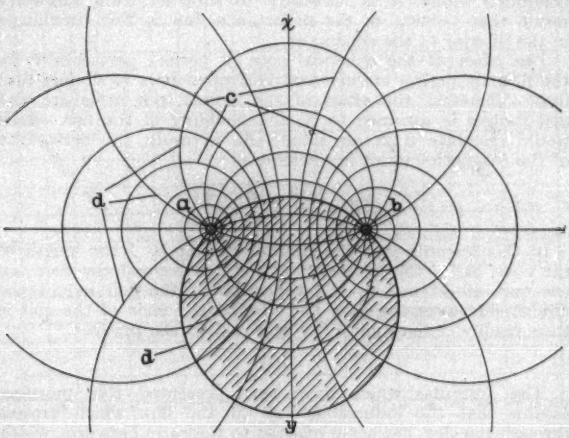


FIG. 2.

count the inductance due to flux within the slots. That must be calculated separately.

Mr. Allen, in his paper, shows that the inductance of a coil in commutation on an armature running in a frame is nearly the same as if the armature were running out of the frame. The fluctuations of current in the coils being commutated tend to set up variations of flux through the iron of the yoke. That iron is surrounded by coils of a large number of turns, which are in parallel with the armature and which act as the short-circuited secondary of a transformer. The effect of the short-circuited secondary is to oppose the variations of flux and nearly to nullify the effect of the iron in the yoke,

so that the total flux surrounding the coil is not much greater than if the armature were spinning in air. Whether the armature be spinning in air or in the fields an approximation can be made to the inductance of the coils by this method of taking an approximating circular coil, computing the inductance of the circular coil on a spherical core of perfect permeability, and adding to this the inductance due to flux within the slots. The details of the calculation will merely be indicated here.

In his "Treatise on Electricity and Magnetism," Maxwell gives the total inductance of a circular coil in air, due to flux circulating both around and within the material of the conductor. To find the inductance due to flux outside the conductor alone, it is necessary to subtract from Maxwell's result that portion of the inductance due to flux circulating in the interior of the conductor.

The effect of the spherical core of perfect permeability on the flux through a circular coil laid upon it is to double that flux. Therefore the effect of the actual iron armature core and flanges is assumed to be the doubling of the flux which would circulate if in air alone. As a result, the permeance of the magnetic circuit in question is

$$P'' = 8.3 \sqrt{p\,(J+l)}\ \log_{.10} \frac{1.13 \sqrt{p\,(J+l)}}{a}$$

In this formula p is the chordal coil-pitch, J the length of the core, and l the extension of the coil beyond the core on one end, all in inches. That portion of the coil inductance due to flux over the slots and around the ends of the coil is then readily determinable, being equal to the product,

$$P'' \times n^2 \times 10^{-8}.$$

The formulas which have been presented this morning assume that the inductance due to the flux which crosses through the slot has some relation to the ratio between width and depth of slot. This flux has a definite relation to the width of the slot; it is inversely proportional. If the coil completely filled both slots in which its conductors lie, this flux would also be directly proportional to the depth of the slot, and that proportion of the coil inductance due to the flux across the slot would be proportional to the ratio, slot depth ÷ slot width.

Actually, however, the coil on one side lies in the bottom half of the slot, although not usually at the very bottom, and on the other side in the top half of the slot, although not usually coming clear to the top. Moreover, there is a space required for insulation and unoccupied by windings in the middle of the slot. Finally, a certain amount of flux crossing at the top of the slot arches up above the height of the teeth, adding to the effective slot depth.

Flux crossing through the winding which induces it has zero density at the bottom of this winding and increases to a maximum at the top of the winding. Below the winding no flux passes, and above the winding the flux density is constant at the maximum value. It results that the inductance due to flux through the coil follows a cubic law, while for that above the coil it does not. Careful computation requires that these factors be included. This is a matter of only the slightest additional labor, after the proper formula has once been written, and may affect the result by 10% or more.

In fact, after the determination of the formulas, the calculation of armature coil inductance by the method described is extremely simple, and may be done in a few minutes. The

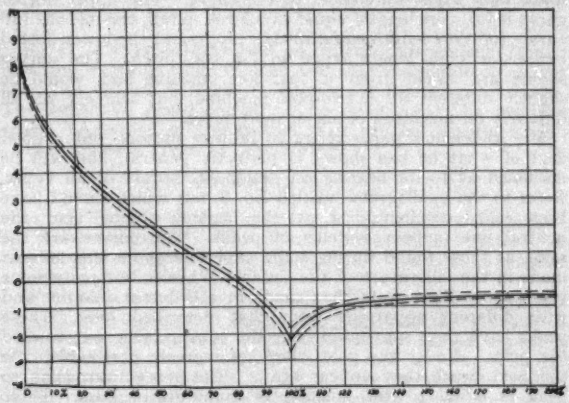


FIG 3.

results obtained are found to be quite accurate; for example, the computed permeance of the magnetic circuit of self-inductance about a certain armature coil was 233, while the experimentally found result was 229, an error of only 1.75 per cent.

Since part of the flux set up by an armature coil passes around the core and through other armature coils, the effects of mutual inductance on commutation are great. Coils in commutation, not only one or two bars removed from the coil in question, but even removed one coil pitch, will have to be considered. The mutual effects of coils not in the same slot are due entirely to the flux which goes over the outside of the core and surrounds the end connections. This can be determined experimentally. Fig. 3 is a curve showing the

mutual effect of two coils when removed from each other by varying percentages of the coil pitch. The effect is greatest when the coils lie near together; it becomes 0 at about 80% removal; is a negative maximum at full-pitch removal; and continues negative on around the core. For removal 0 per cent the coils coincide, and the ordinate of the curve represents that portion of the self-inductance due to flux around the core and around the end connections. The mutual inductance of two coils not in the same slot is therefore obtained by substituting the ordinate taken from this curve for the factor 8.3 in the formula for P'', the permeance of self-inductance due to flux around the core.

Great changes in the relation of core-length to coil-pitch make only slight differences in the curve. The upper dotted curve is for core length equal to 0.5 coil pitch, the middle full curve for core length equal to coil pitch and the lower dotted curve for core length equal to 1.5 coil pitch. The curves shown are taken from a four-pole machine and would be slightly different for a two-pole machine, but scarcely at all different on machines of six or more poles.

Mr. Anderson's paper refers to railway motors, but a good deal of what he has shown is perfectly general, and will be discussed as to its bearing on design of motors of all types. Refer to the oscillogram entitled No. 3, but which should have been called oscillogram 4, at the neutral points, near the neutral line, appear systems of peaks. The curves are the same as those found during some experiments on this subject made in the laboratory of the Crocker-Wheeler Company some years ago. They were then made in a different manner and with different apparatus from that described here. These peaks have their maximum near the brush, dying out toward the poles. Under the poles they are scarcely noticeable. At the next brush they appear again. The space from peak to peak is equal to the spacing of commutator bars. These peaks are peaks in pressure between adjacent bars. As the commutator moves forward the pressure between two bars is continually varying as shown by the curve. Even when two bars are short-circuited by the brush these same waves are found. A curious thing found was that in the region lying a slight distance beyond the toe of the brush the curve is very unstable, so unstable that it is almost impossible to determine it. The form of the curve as a whole in this region appears to vary from bar to bar continually. This peculiarity has not yet been cleared up. As stated at the bottom of page 373 and top of 374, these peaks are caused by mutual inductance with other conductors being commutated, conductors which may be several slots removed from the coil in question, or even under the next pole.

There is a close relation between the heights and locations of the peaks and the operation of the machine. Under certain

conditions these peaks will be high near the heel of the brush, and under other conditions high near the toe. It is under the latter condition that severe sparking is found to occur. Slight visible sparking, or sparking which is invisible, being under the brush, may take place when high peaks occur back from the brush toe. The sparks caused by this may be carried forward to the toe and show slightly. Under conditions of heavy load or otherwise the peaks move forward until one of them reaches the toe, when the sparking becomes vicious. The difficulty in finding a satisfactory criterion of sparking arises from the difficulty in telling where the peaks will come and how high they will be. To determine this it will be necessary to take into account not only the self-inductance of the coil, but its mutual inductance with every coil which is in commutation.

R. B. TREAT:—There are so many independent factors affecting sparking that it does not seem advisable to collect them all within a single "Criterion of Sparking" formula. The collective result might be favorable—and the machine spark. Any one of the factors may be the disturbing one.

The equation given by Mr. Waters,

$$C = n^2 (l k + p c) N I f P Q$$

does not include several sparking factors equally important to those mentioned. We should, however, be grateful to him for presenting the "Inequality factor" to us in so tangible a form.

W. L. WATERS:—Mr. Anderson calls attention to the fact that in the oscillogram shown on page 371, the pressure is indicated at about four volts, whereas we should expect a self-induction pressure of only about half a volt. The explanation of this appears to the speaker to be quite simple. When running with brushes on the neutral point, we are, in reality, running in a magnetic field, which is by no means zero. The magnetic field due to magnets, is zero, but the magnetic field due to the cross magnetization of the armature is considerable. This is shown quite plainly in oscillogram No. 6. The fact that the short-circuited armature coil is running in this magnetic field causes a large short-circuit current to be induced in this coil, and it is the breaking of this short-circuit current rather than the commutating of the normal armature current which causes this high e.m.f., shown in the oscillogram. The correct way to obtain an oscillogram indicating the self-induction e.m.f. due to the commutation of the armature current would be to take the armature and run it without the field magnets, passing full-load current through it. This method was, I think, proposed by Gano S. Dunn about eight years ago.

Referring to Mr. Anderson's statement that you can run with impunity with 5, 6, or 7 coils per slot, the speaker wishes to point out that this is due to the peculiar conditions, which you have in a railway motor. The magnetic field at the neutral point varies very slightly as we move away from the exact neutral. The field due to the magnets is zero, while that due to the armature is at a minimum point. The result of this is that a small variation of the point of commutation from the exact neutral is not of much consequence. But these conditions do not by any means apply to the standard direct-current generator. The magnetic field at the point of commutation in a direct-current generator varies very rapidly, and hence the slight inequality of the position of commutation, caused by using four or five coils per slot, produces quite a considerable variation in the sparking conditions, so that the case of a railway motor must be considered as quite a special one in respect to the possibility of using several coils per slot.

THORBURN REID:—The speaker is very much interested in Mr. Waters' paper, especially with reference to the inequality factor, which appears to him to be an ingenious solution of that problem. Just what fact Mr. Waters' assumption was based on is not clear, the only one shown being the figure on page 363, and the speaker is unable to discover upon what physical fact that figure is based. Mr. Waters said it gave him a formula which enabled him to design dymanos within 10% of accuracy as far as sparking was concerned; that being the case, the speaker does not think the establishment of an actual basis for his assumption is a matter of any importance.

What the speaker especially wishes to draw attention to is the sparking constants given on page 368 and the cause of their variation with different numbers of poles. One part of that variation, he thinks, would be found to rest on one of the elements of the formula for the sparking constant; that is, the inductance e.m.f.

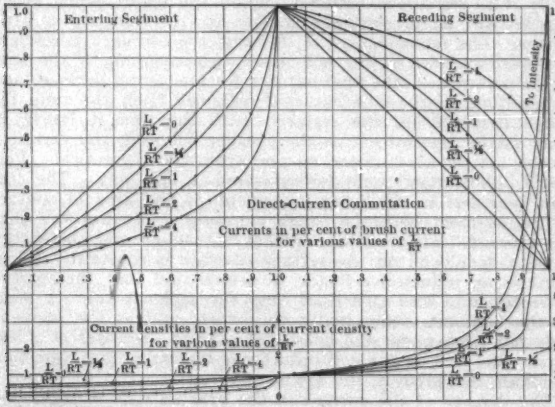
The speaker has been working for the last two or three years, as he got time, at this same problem of a sparking constant and has gotten his investigations nearly to the point where he is ready to bring them before the INSTITUTE. He is sorry he could not get them ready for this meeting, but has gotten far enough along to be able to give the members at least one piece of information on the subject that he hopes will be of value, and would like to give it now, in advance, in order that others who might have a chance to make experiments on the sparking constants of dynamos may be able to take up these constants by experimental work. The speaker has no facilities for doing this at the present time.

The speaker found that with one set of brushes the variation of the current from what might be called perfect resistance commutation depends, not on inductance e.m.f., but on the

ratio of the reactance to the contact resistance of the brush surface. The reactance pressure may vary very widely without affecting this ratio at all; on the other hand, the reactance pressure may remain constant and this ratio vary very widely. Mr. Waters' constant is based on reactance pressure alone and apparently as the number of poles increases there is a change in the ratio of the reactance to the contact resistance which has something to do with this change in his constant. If that factor were used in place of the reactance pressure, the speaker thinks he would find an entirely different relation in the variation of the constant. What it would be the speaker cannot say at the present time, because there is another factor affecting it of which he would speak later, which had come within the range of his investigation in the last few weeks. That ratio the speaker would put on the board which would enable him to present the matter to the members a little better. The factor is $L/R\,T$, L being the ordinary coefficient of self-inductance of the coil under commutation, R the contact resistance of the commutator for the brush surface, and T the time of the commutation reckoned from the time the brush first touches the segment until the time it leaves it. That factor determined, as the speaker has said, the variation of the actual commutated current from the theoretical. Perfect commutation might be expressed in this way. The current increases in the same proportion as the area of contact of the segment with the brush increases, in such a way that the current density on the segment is constant and the energy density developed on the segment surface is constant. When there is an inductance factor we would find that the current increases at a less rate than does the segment contact area, as the segment comes under the brush, and as the segment goes out from under the brush the current decreases at a less rapid rate, and as the coil inductance increases, that variation increases, as shown in the figure.

The density of the current in the brushes with straight-line commutation is constant. With the distortion due to inductance the current density gradually increases all the way from the beginning of the commutation to the end, and as the ratio L/RT increases and the curve varies still more from perfect commutation, the current density comes up higher and higher until finally at the end of the commutation period with high values of L/RT, the current density reaches infinity theoretically, so that the values of the factor L/RT enables us to determine, as the speaker will show when he is able to present his paper at the INSTITUTE, both the total increase of the energy developed at the brush contact-surface during the commutation period and the law by which this energy varies during the commutation period; and gives the means of forming a sparking criterion which the speaker hopes—he might say he ventures to hope—will be general in its application to all the different forms, at least of generators.

A further factor that affects this question is the frequency of the commutation periods. As a segment goes under the brush it receives energy in its different parts in different amounts; that is, the part that touches the brush first gets very little energy. The edge that leaves the brush last generally gets a maximum of energy with the result that the sparking or pitting usually occurs at the receding edge of the segment. The segment has energy poured into it through each brush as it passes underneath it; as it passes from one brush to the next, energy is conducted and radiated away. The speaker thinks the amount radiated has little bearing on the final temperature of the receding edge of the segment; that the main point is the amount that is conducted away


Entering Segment
Receding Segment
% Intensity
Direct-Current Commutation
Currents in per cent of brush current
for various values of $\frac{L}{RT}$
Current densities in per cent of current density
for various values of $\frac{L}{RT}$

towards the center and front edge of the segment, but during the time the segment is passing from one brush to the next, its temperature falls, and when it goes under the next brush it receives another block of energy which raises the temperature again, until finally, if the sparking constant is too high, the temperature is raised to the melting point and pitting occurs. The speaker has determined the increase of energy due to the increase in the sparking constant at each commutation period, thus leaving that to be multiplied by the number of commutation periods in a stated time in order to arrive at the total amount of energy poured into the receding edge of the segment, and that is the part of the investigation that he has not yet been able to take up. But he would like to ask those of the members who have had a chance to make

the calculation to use in their formulas the criterion of sparking L/RT in place of the inductance e.m.f., and see if it does not give them better results. The speaker thinks it will give better results because it is nearer the truth of the actual conditions of commutation.

The speaker would say one word in conclusion regarding the calculation of the self-inductance of the armature coil. He did a considerable amount of work on that some years ago and reached such very discordant results that he came to the conclusion that the simplest possible method of calculating the inductance, at least in practical work, was the best. Mr. Waters' method differs from his slightly, perhaps he should say it differs from it a good deal. Instead of using the total depth of the slot, as Mr. Waters did, the speaker used the depth of the slot above the winding. The width of the slot he used as did Mr. Waters. He had tried various other methods but did not find any of them to be especially accurate.

Mr. Waters has shown even by these rough values given for the sparking criterion some variation which has not been explained as yet, so that these very accurate determinations of the self-inductance seems to the speaker, at least at the present stage, to be refinements not warranted in practical work.

The speaker hopes that he will be able to present the formulas and curves on which his sparking criterion is based at an early date. As he had said before, he would be very glad indeed if any of the members who were able to calculate or make over their calculations on sparking constants would use the ratio L/RT in place of reactance pressure, and he will be glad to have any information on that subject, because he can assure the members that the investigation he has been making is about as complicated and as difficult as any he has ever tackled in his long experience.

E. H. ANDERSON:—One or two points the speaker would like to bring out. In the reactance formula, Mr. Waters says L is the length of the armature and K is the slot constant. Mr. Reid understood it to be the relative value between the width and the depth. The point the speaker wishes to bring out is this—that there is a permeance between tops of teeth in addition to that through the slot above the copper and through the slot where the copper is located. Including these three factors gives a permeance that works fairly well in determining the sparking value. However, in the discussion it was brought out that there was permeance from all tooth tops enclosed by coil which simply increases the estimated pressure possibly not over 10 per cent. Estimating by either of these methods will give a set of comparative numbers, and that is all the method gives anyway. A point was brought out by Mr. Reid which is good. One can calculate the tendency to spark according to Mr. Waters, but the actual com-

mutation depends upon how much energy is liberated on the commutator and how well the commutator handles it. Mr. Waters speaks from the direct-current generator standpoint, and the oscillograms given in the speaker's paper are from the railway-motor standpoint. The railway motor does not need to have its pressure across the commutator bars continuously. Consequently, we can use a radical distribution of conductors. We can use self-induction of commutation two or three times as high as in generators for the simple reason that the power is on at low pressure to start with; it rises with full intermittent current to full pressure and then the current drops, so that half of the distance through which the cars travel the commutator is polished. If there had been etching going on all the time, the commutator would not operate so well. Consequently, following out this idea, a railway motor on a particular duty may commutate well indeed; put it on another duty where the pressure and current are on longer, the motor may be heated somewhat more and the etching is too great for the polishing, with the result that the commutator does not run well. So it is possible to have the same motors on approximately the same service, but the service be different enough for one commutator to run bright and one to run black and give a lot of trouble in flashing. It comes down to the question that Mr. Reid brought out,—that the proper way to see whether a commutator is going to work satisfactorily in service is to find out how much energy is delivered to it and how much it can stand. However, the sparking value and the stability of the machine are a pretty safe indication as to commutation in service.

The large number of coils per slot and the high sparking quality all naturally go with a large motor in a small space, and it is only by reason of being in the railway service and having a polishing period that the commutator is really able to run so well. So that the question of design taken up in the speaker's paper relative to railway motors and the question of design taken up in Mr. Waters' paper relative to railway generators of course must be quite different. The speaker was very much interested, and agrees with Mr. Waters very decidedly in his inequality factor, because he has seen a one-coil-per-slot machine run very well although its calculated sparking was high. Three- and five-coils-per-slot machines require lower reactance pressure (calculated) in order to run as well, comparing somewhat in the order of 10, 7, and 6 for one-three- and five-coil-per-slot machines respectively.

W. S. FRANKLIN:—It seems to the speaker that the loss of pressure in direct-current machines on account of inductance of the armature sections is a phenomenon identically the same, from a physical point of view, as the "skin effect" in large wires. The analogy can be made clear as follows: on account of inductance in the armature section, the arma-

ture current is made to follow a larger resistance path in flowing through a section than it would if there was no inductance in the section, because then the current would go directly to the brush. The effect of inductance of armature sections is to increase the resistance of the armature between the brushes. On account of this increased resistance of the armature between the brushes there is an increased loss of e.m.f., exactly as in the case of a wire.

CLARENCE P. FELDMAN:—Mr. Waters considers only the self-induction of the windings and the effect of inequalities produced by placing more than one coil into each slot. Now it is well known that a four-pole series-wound armature will run without any sparking, even with the inequality produced by using, say, 93 coils and 47 slots.

On the other hand, he greatly underestimates the influence of the shape of the pole pieces; the main difference in European direct-current dynamos is to be found in the shape of the pole pieces, special forms of which have been patented by Kando, Arnold, and others. The reactance pressure, which is strongly advocated by so able a designer as Hobart, is a safe guide only for one special type of machine; it is merely a rule-of-thumb that has to be changed for every new design. A machine with high reactance pressure may work all right, and another one, with low reactance pressure, may show a tendency to spark.

Mr. Anderson's beautiful oscillograms, especially Fig. 1, page 371, show clearly the five points corresponding to the five coils per slot, a lower one and four of about equal height. His statement that a motor of identically the same design will commutate better at 250 than at 500 volts seems somewhat misleading or inexact. If he takes the same current at the same speed and half the field, the commutation will be worse; if he takes, as he probably intended, half the current at half the pressure, the commutation will be better, as he commutates one-half the current at one-half the pressure, or one-quarter the energy per bar.

The results obtained by Mr. Anderson with what he calls "standard fields" show that the short-circuited winding acts as a damper, impeding any rapid change of current or pressure. This explains the low rise of pressure in Fig. 8, as compared with Fig. 9, and the slow drop from it to *B*, Fig. 10, as compared with Fig. 11.

Mr. Reid has justly stated that not only the self- but also the mutual-induction between adjacent armature coils should be taken into account, and that other points, *i.e.*, the frequency of commutation, the contact resistance of the brushes, etc., are of marked influence upon commutation. He seems to be on the right path, but Professor E. Arnold, of Karlsruhe has, with the assistance of Professor Mie, now of Kiel, completely solved the differential equation for the case in question in

'98, and has lately, in his book on continuous-current machines, succeeded in showing the real shape of the commutating field for a novel design, taking the shape of the pole piece, self and mutual induction, number and width of bars, width and resistance of brushes, etc., in consideration. The single rule which he gave in his first paper was $\frac{TR}{L} \geq 1$, where

T = period of commutation.
R = contact resistance per cm.^{2}
L = inductance.

In his new book he completes his formula by giving all data necessary to figure self and mutual induction for any arrangement of coils in the slots.

W. S. FRANKLIN:—Whether mutual inductance as well as self-inductance of the coils in a slot need to be considered in connection with the theory of commutation seems to be open to question. It is very doubtful if mutual inductance has much to do with it. There is actually one current changing at one time, and that is the current in one coil, unless, of course, the brush spans three or four commutator bars, and then the mutual inductance effects need to be taken into account.

THE PRESIDENT:—The paper yesterday showed that it did.

H. WARD LEONARD:—For the past 15 years the speaker has advocated the use of separately-excited field magnets for railway motors, in place of the ordinary series winding, and has pointed out theoretically the great difficulty that would arise by suddenly applying pressure to a series motor, indicating the results found by Mr. Anderson. The series motor formerly was generally used in elevator service, which is very similar to railway service, but has been practically given up for this use. The importance of having the field magnets fully excited when the pressure is applied to the armature is very clearly brought out in the paper in question. In examining the papers that have appeared in the last six months, on the single-phase railway motor, the speaker has been struck with the fact that the chief virtue claimed for the single-phase railway motor has been that it is a series motor, and therefore the only proper kind of motor for railway work.

The speaker has recently changed the field winding of an automobile motor from series to separately excited, and as a result, in addition to having more perfect control of the car, has found that the fields practically reach saturation at 120 watts, while the series field, on the same grade, required 1100 watts. The separately-excited field can carry 120 watts indefinitely, whereas with 1100 watts they would soon be destroyed. The principal reason, in the speaker's opinion, for the use of series motors is the matter of patents.

[COMMUNICATED AFTER ADJOURNMENT.]

THORBURN REID:—It was brought to the attention of the writer at the meeting by several members after he had spoken, that the sparking criterion, $L/T\,R$, has already been deduced by Arnold and Mie in Germany, a fact of which he was not aware at that time. In fact, the writer had not known of their investigations at all until some time after his own equations were deduced, which in their differential form are similar to Arnold's and Mie's, but in their integral form are entirely different.

The fact that the current density at the end of the commutation period would theoretically reach infinity for any value of $L/T\,R$ equal to or greater than unity, the writer had also deduced before he had heard of Arnold's and Mie's investigations, but while he agrees with them that sparkless commutation can probably not take place if $L/T\,R$ is equal to or greater than one, he is satisfied that sparking can take place for values of $L/R\,T$ very much less than unity and also that sparking may occur for values of $L/R\,T$ equal or greater than unity that will not, however, injure the commutator in any way. The writer's explanation of these facts is too long to give now and will be given in full in the paper he is preparing on the subject.

The writer wishes to add that on reading over his paper on "Sparking; Its Causes and Effects," read before the INSTITUTE in December, 1897, he finds that the method of analysis afterwards used by Arnold and Mie was suggested in it and that the sparking criterion finally reached by their analysis was given in the writer's paper with the difference that, as he had not at that time made any mathematical analysis, he did not know that the resistance of the coil under commutation could be neglected as compared with its reactance, and therefore gave the criterion as the ratio of the impedance of the coil under commutation to the segment contact resistance.

DISCUSSION ON "ON THE CALCULATION OF LINE BATTERIES."

F. J. WHITE:—Doctor Winship states that the best method of determining the average running current per car is by station wattmeter readings. That method will give the average current for the average car, but not the variation of the current throughout the line, and very often that variation will alter the location of the centre of gravity. Take, for example, an interurban line; it will be found that the traffic is heaviest near the city and that there is an increase of the average current of the car over this section, which throws the centre of gravity nearer that point. With regard to sub-stations versus the line battery, where the average schedule is light, say half-hour or hourly cars, we find the battery is more economical to install; that is, it is cheaper in the first cost and the running expense is considerably less. Of course, this only

applies where the consumption of power is small and the peaks are heavy in comparison to the average work.

LAMAR LYNDON:—The speaker notes the results that Doctor Winship has obtained correspond in general with those of M. Sarrat, of Brussels, who developed a graphic method which was published in the *Revue Electrique* of February. 15, 1904. The speaker also obtained similar results which were published in 1902, and which practically correspond with Doctor Winship's. In the formulas of M. Sarrat and the speaker, the internal resistance of the battery was considered, and this Doctor Winship has apparently neglected. The internal resistance of the battery is made up of a number of factors, the principal of which is polarization. There is a definite drop on discharge, and a definite increase of pressure on charge, and this factor must be reckoned with. Also the character of the generator from which the load is supplied must be considered; that is, in Doctor Winship's equations, V_1 and V_2 are considered fixed pressures, whereas V_2, at least, is variable; V_1 is variable unless the generator be compounded for constant pressure. The variation in the value of V_2 will shift the minimum point of line pressure; that is, the vertex of the parabola, indicated by equation top of page 386, will shift in its location between two stations with load changes.

The resistance of the battery is not merely of academic interest. Its practical importance may be indicated by citing some computations which the speaker made on an equipment for a line battery placed at some distance—five miles—from the power station and controlled by a constant-current booster in the station. Two sets of calculations were made. In the first the changes in V_2 with change of load were allowed for, but there was no account taken, however, of the change in the location of the point of maximum pressure drop; that is, the point of minimum line pressure. As one of the results, the booster required, worked out 24 kw. with a correspondingly large driving motor. A re-computation, in which the factor of change in position of minimum line pressure due to the drop in battery pressure on discharge was taken into account, showed that the proper size of booster for this particular piece of work was 12 kw. In other words, it cut the size of the machine in two, with its attendant losses.

In a constant-current booster, feeding a line battery, the total booster input is lost. This, therefore, is a practical question. Of course, with Doctor Winship's equations, if two or three values of V_2 are assumed, accurate results would follow; but as they now appear, the speaker should not say that they are general equations.

W. E. WINSHIP:—With reference to Mr. Lyndon's criticism that the virtual internal resistance of the cell should be taken into consideration in calculating a line battery. It has not been the experience of the speaker that it is possible to obtain expression of this sort which one could work with for this

purpose. The potential difference of a cell is a function of two variables: the current charge or discharge and the time of its duration. This potential difference is not a linear function of either of these variables, but is an extremely complex expression and the periods of discharge and charge are variable. The calculations as given in the paper conform with results obtained in experience to within one or two per cent.

With regard to variable running currents on different sections of a road. It is well to increase the average running current at points where grades occur, especially if they are long and serious, thereby allowing for the increased consumption at such points. The assumed currents can vary three or four per cent. and not affect the final results seriously. A variation of three or four per cent in the running current means a corresponding variation in the drop to the battery; this means only one or two cells difference in the installation, and one does not expect to calculate a line battery closer than this.

THE PRESIDENT:—The speaker is much interested in line batteries just now, having under consideration the equipment of eight sub-stations, and if it is decided to use batteries this will be the largest installation of batteries, judged from the standpoint of first cost, yet attempted. In general, however, when a regulating booster is not used. The speaker has always made it the practice to connect up a number of the terminal cells with a lead to each cell and connect these leads through single-pole switches to a bus-bar extending along the tier of cells, in such a manner that more or less cells could be cut in, depending on the daily load, in order that the battery may be kept properly charged when floating on the line. It is not unusual to install five to ten more cells than are needed in normal operation. The speaker usually installs a certain amount of capacity in battery plates and leaves room in the tanks for the installation of as much more as conditions, due to natural growth of the plant for a few years, may warrant. For this reason the best calculations seldom fit a case on the start, or if they do they are not correct for the plant soon after it is placed in operation.

DISCUSSION ON "DATA AND TESTS ON A 10 000-CYCLE-PER-SECOND ALTERNATOR."

F. D. NEWBURY:—The speaker had the interesting experience of testing this high-frequency generator. Mr. Lamme has given fully the results of these tests, but the speaker may add something of interest concerning how the tests were carried out and the incidents that occurred during them due to the use of this frequency.

MEASUREMENT OF PRESSURE.

As Mr. Lamme has said in the latter part of his paper, the Weston voltmeter was entirely unsuited for use at this frequency, on account of its high inductance. At the time the

generator was completed and ready for test Mr. Walker had in the testing department an electrostatic wattmeter which he was developing at that time. By a very simple change in connections this wattmeter could be used as an electrostatic voltmeter, which gave an instrument obviously suited for measurement of pressure at this high frequency. The current taken by the instrument as a condenser was entirely negligible even at 10 000 cycles. The static instrument gave very satisfactory results both as a voltmeter and later on as a wattmeter in some tests for iron loss in samples of sheet steel. The Cardew voltmeter mentioned by Mr. Lamme was of low range—150 volts—and was used only as a check on the static instrument at low pressures.

Iron-Loss Tests.

Mr. Lamme mentions that difficulty was encountered in obtaining satisfactory results in the iron-loss tests. These tests were made in the ordinary way with separate direct-current driving motor, the losses being measured as part of the driving-motor input. The most important reason for this trouble was the small value of the iron loss compared with the friction losses. For example, at 150 volts and 3000 rev. per min., the friction loss is 4000 watts while the iron loss is less than 200 watts. In addition, any fluctuation in the supply pressure of the driving-motor circuit caused an exchange of energy between the revolving generator field and the electrical circuit that caused fluctuations in the electrical input to the motor.

Consistent results were obtained by taking a large number of independent readings and by plotting auxiliary curves in the following ways:

From the data for different frequencies preliminary curves were plotted with watts and field amperes as coördinates. In these curves the points from different tests checked closely for high inductions but for low inductions the points from different tests were widely scattered. In order to locate the lower part of the iron-loss curves, curves were drawn for different field amperes with watts and frequency as coördinates. These curves showed the loss very nearly proportional to the frequency. For this reason the lower part of these curves could be accurately drawn as they were very nearly straight lines. Final watt field-ampere curves were plotted from coördinates taken from the watt-frequency curves.

Short-Circuit Tests.

It was necessary to obtain a current reading with small pressure drop. A dynamometer with a small number of turns was secured for this purpose. A hot-wire ammeter was also tried. On account of the retentivity of the forged-steel field the residual pressure of the generator was large and at the high speeds was large enough to circulate full-load current through the armature on short-circuit. For this reason the magnetic circuit had to be demagnetized before each short-circuit reading.

EFFECTS OF THE HIGH-FREQUENCY CURRENT.

(a) The coils of the dynamometer used became very warm with small current. This was probably due to so-called "skin effect" of the eddy currents generated in the wire.

(b) The eddy currents in all parts of the circuit were very marked. The stray-fields were also marked. During tests it was necessary to separate instruments widely.

(c) With sheet steel of ordinary thicknesses temperature rise was so great on account of iron loss that nothing could be done.

(d) It was attempted to measure high pressures obtained from air-core transformer by spark-gap, but as soon as spark jumped an arc was formed which burnt up the needle points.

(e) Very marked resonance effects were obtained with an air-core coil and condenser of usual construction connected in series.

F. B. CROCKER:—It would be well to remind the INSTITUTE that Mr. Tesla had a machine similar to this one which he used in his high-frequency experiments in 1891. He had it operating at Columbia University, where he gave a lecture. This machine was designed to give about 10 000 cycles-per-second. (See TRANASCTIONS, Vol. VIII., page 267.)

DISCUSSION ON "NOTES ON FLY-WHEELS."

H. H. BARNES, JR.:—The suggestion is made in the paper that the angular variation of the prime mover is not necessarily responsible for the cumulative surging of alternators operated in parallel. The usual argument advanced to prove the opposite is the behavior of water-wheel driven units, with which cumulative surging is unknown. This argument, however, is not conclusive, as will be seen from a more careful consideration of the conditions.

Let us assume that two alternators direct connected to water wheels (turbines or impulse wheels) are thrown together a little out of step, thus producing oscillations, which, it is needless to add, will be natural ones. The two machines will then oscillate back and forth, one machine traveling too fast when the other is traveling too slow. But this variation in speed means a variation in the driving torque of the wheels. As the speed rises above normal the driving torque decreases and *vice versa*. We have, therefore, in this variation of the driving torque a parallel to viscous damping. This variation will assist whatever electrical damping there may be in the machines, and the alternators will settle down to steady multiple running.

Let us now consider for a moment the behavior of alternators direct connected to overshot water-wheels. If we assume that the same amount of water is delivered to the individual bucket, irrespective of variations in the speed of the wheel, the driving torque of the wheel will remain constant regardless of the speed, and the driving power will vary as the

speed, a condition tending toward instability. The conditions in this case, therefore, differ considerably from those existing when turbines are used. As a result of this difference, it seems highly probable that alternators direct connected to overshot water-wheels and equipped with heavy fly-wheels would not operate satisfactorily together and that cumulative surging would set in.

If we turn now to the action of a reciprocating steam-engine equipped with a delay dash-pot, or, better still, with an entirely-blocked governor, we see that in a broad sense the action of the engine strongly resembles that of the overshot water-wheel while it differs from that of the turbine. At all events, we are not justified in saying that because turbine-driven units operate successfully, alternators direct connected to reciprocating-engines would do so also if it were not for the lack of uniformity in their driving torque. The two cases are not sufficiently similar to be compared in this way.

The same may be said of belt-driven units. Furthermore, the fly-wheel effect provided is always much smaller for water wheels and belt drive than it is for direct connection to engines. This gives a higher natural frequency and consequently more vigorous electrical damping, which, in itself, is an additional source of stability in favor of belts and water-wheels.

The statement that with a 70% ratio of frequencies the angular variation of an engine running singly may be doubled upon throwing two machines together, needs a little explanation. We would certainly get this increase—according to the general laws of resonance—if the original displacement followed the sine law and had a period equal to that of a revolution of the engine. In reality, however, the displacement curve is irregular. When developed into a Fourier series, we find that the maximum amplitude usually belongs to the second term, which has a period equivalent to half a revolution of the engine. The amplitude of the first term, with a period equal to one revolution of the engine, is relatively small. As there is a doubling of the amplitude of the first term only, and an increase of but some 15% in the amplitude of the second term, it is really unfair to say that the maximum displacement originally calculated for an engine running singly is doubled upon throwing it in with others. This extreme case, it is safe to say, will never be realized in practice. We have, therefore, this additional margin of safety to protect us when we use the formula for fly-wheels suggested in the paper. Instead of getting cross currents equal to 25% of the full-rated current as a maximum—which we might get if the original displacement were doubled—we may expect to see the cross currents limited to 15 or 18% at the most. This additional margin is ample to take care of any unbalancing of load between the cylinders of the engine, or of any other similar emergency that may arise during routine operation.

W. S. FRANKLIN:—Two or three years ago the speaker worked out a mathematical development which bears upon this question; namely, the theory of hunting and its dependence upon field distortion and pressure regulation of alternators. A final equation was reached, the denominator of which covered two pages and the numerator seven pages of paper, hence it was never offered to the INSTITUTE.

In the case of an ordinary undamped mechanical oscillation the force of restitution for a given displacement is the same on an outward as on a backward excursion. In this case the oscillation has no tendency to grow larger and larger, and if there is any damping whatever it has a tendency to grow less and less. If, on the other hand, we had a mechanical system in which the force of restitution for a given displacement were greater on a return than on an outward excursion, there would be a tendency for the oscillations to grow more and more violent, unless the tendency is balanced by very great damping. Now, in the case of an alternator connected to a synchronous motor, we have conditions exactly analogous to this second case. That is to say, the forces which tend to bring the two alternators into their normal, steady, running relation with each other are greater while they are returning toward that state than while they are departing from it, and consequently their oscillations have a tendency to increase. The cause of this is as follows: in the first place any change in the e.m.f. acting on a system requires some time for the corresponding change of current to become established. In the second place, as two alternators oscillate with respect to each other, the resultant e.m.f. is continually varying in value, and the current conditions in the system do not keep pace with the changing e.m.f. conditions; so that the current values, while the system is departing from a certain state, do not correspond to the current values while the system is returning to that state. The result of this is that the oscillations of the synchronous motor are increased on account of the fact that torque values, which correspond to current, are greater while the system is returning to its steady running configuration than while it is departing from it. Therefore, any slight disturbance of the synchronous motor tends to cause a continual increase of violence of hunting oscillations unless balanced by damping.

Can Mr. Barnes say whether the increase of damping observed when the exciters were connected in parallel might not be ascribed to the fact that the field coils under these conditions act like short-circuited copper conductors around the field poles.

H. H. BARNES, JR.:—The speaker would say that as he understands Professor Franklin, we would get the same result if we excited the two alternators from one exciter.

W. S. FRANKLIN:—Yes.

H. H. BARNES, JR.:—If you excite from one exciter, you

also have the two field circuits in series. This was tried, but no change was noticeable in the surging; it proceeded exactly as it had done before when separate exciters were used. The following test was also made. Thinking that by cross-connecting the exciters we might possibly counteract the effect of any variation in speed and stifle the tendency to surge, each alternator was excited from the exciter of the other. But we found no change whatever in the behavior of the machines. The only way these machines could be made to hold together was by paralleling the exciters. Therefore the speaker believes that the only correct explanation is that we actually have a pronounced damping effect in the exchange of energy between the two exciters as the two alternators oscillate back and forth.

CLARENCE P. FELDMAN:*—Mr. Barnes is correct in saying that gas-engines driving alternators need less fly-wheel capacity and heavier damping. Mr. Rosenberg, formerly chief engineer of Koerting's Works at Hanover, has tested this point by paralleling three-phase alternators with light fly-wheels. It is not probable that it was by chance that Le Blanc, of Paris, made the experiments with his damper at St. Ouen with a single-cylinder steam-engine. Some two years ago, the speaker was asked to give his opinion upon the question of the operation in parallel of two stations in Italy, having alternators of different construction,—one with two slots per pole, the other with three, the smaller alternators had a less drop in pressure than the larges ones and very bad hunting resulted,—particularly when the smaller alternators were used as synchronous motors. The speaker advised heavier damping, and the use of self-induction in the line, but is not informed whether the remedy was successful.

As Mr. Barnes has said, Boucherot has given a formula for the fly-wheel,—perhaps the best there is. Professor Georges, of Dresden, has put the mathematical work into simpler form; he has done as Rosenberg did, that is, has made vector diagrams, and has shown, as Mr. Barnes has done, that the weight of the fly-wheel may be decreased when the prime mover has slight uniformity of angular velocity, as in the case of a gas-engine.

H. H. BARNES, JR.:—Referring to Professor Franklin's remarks, is the speaker correct in assuming that his explanation of the development of the inherent tendency to surge is independent of the angular variation?

W. S. FRANKLIN:—Oh, yes, indeed.

H. H. BARNES, JR.:—Therefore we do not have to introduce the angular variation of the engines to explain cumulative surging? Faulty paralleling, or a sudden variation in load, or a change in excitation will do as well?

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*Polytechnic High School, Darmstadt.

W. S. FRANKLIN:—Not at all. It merely requires a disturbance of equilibrium. If you start the oscillations, and if the force of restitution is greater while the thing is coming back than while it is going outward, it will keep on increasing.

H. H. BARNES, JR.:—The speaker believes damping is a good thing in every case. He is thinking of it, however, less in connection with any effect it may have upon the angular variation of the engines than in connection with the inherent tendency to surge. Angular variation in the engine is, after all, not a serious drawback. But the inherent tendency to surge must be neutralized or counteracted in some way, or the machines will not hold together. And the best way to neutralize it is to provide sufficient electrical damping. As regards the various formulas that have been developed for the natural period of alternators, it is true that a number of others have worked along the same lines since Boucherot presented his original paper, foremost among them being Georges and Kapp.

W. S. FRANKLIN:—The speaker believes that the inherent tendency to hunting depends upon the inductance of the circuit, inasmuch as the inductance of the circuit is the chief factor which determines a delay of the building up of steady-current conditions in the circuit.

CLARENCE P. FELDMAN:—The speaker has never used a damper, but has frequently used steel pole-pieces, which, in themselves, act partly as dampers. In the first German alternating-current station, at Cologne, at first cross-connections were used with the exciters, but later each alternator had its own exciter; there was, however, no difference shown in the results. This station had at first 400-kw. machines, afterwards several 1000-kw. machines were added, and for a time the municipal authorities were afraid to operate them in parallel, on account of hunting. The larger alternators had a coefficient of angular variation of 1/350, with very heavy fly-wheels, and a regulation of 10% on non-inductive load; the smaller had a coefficient of 1/220, and a regulation of 18 per cent. The speaker advised that they could be operated in parallel without trouble, because the smaller machine would be pulled around by the larger, and this proved to be the case. The smaller machine could be used only on non-inductive loads; when used with motor-loads, they did not add appreciably to the output of the station. There was some trouble at the station at first; one of four identical sets gave signs of hunting; but the trouble was remedied by altering the dash-pot on the engine.

The question of hunting is very complicated; it may be started by partly electrical or partly mechanical disturbances. The speaker has had no trouble with hunting, having always used heavy fly-wheels, which, with the damping induced by the steel poles or by short-circuited coils on the pole-pieces, has prevented trouble of this character.

H. Y. Hall, Jr.:—Professor Franklin made reference to the possible damping effect of the field coils of the alternators. The speaker has frequently noted, in connection with the alternators of the Manhattan Railway Company, that there is a slight continuous oscillation or vibration of the field-ammeter needles, which shows that there are induced currents in the fields. It has also been noted that whenever a dash-pot sticks or a valve-hook of an engine misses this effect is increased quite materially and that the increased oscillation is of the same frequency as the oscillation of the engine.

The President:—In other words, the oscillations of the needle correspond to the stroke of the dash-pot?

H. Y. Hall, Jr.:—Whenever it misses.

Clarence P. Feldman:—Boucherot has shown that the effect of the armature reaction of an alternator is transferred to the armature of the exciter by reason of its effect on the field of the alternator. In an old station, the speaker had an exciter with the field of sheet-iron, having a very high armature reaction; this exciter always sparked when exciting the field of the alternator, but did not spark when working on a water-load; the oscillating pressure produced in the field could be shown by means of a transformer; the difficulty was overcome by the use of a cast-iron field in place of the sheet iron. This may account for some of the advantages found by Mr. Barnes in connecting one exciter to two alternators, or in cross-connecting the exciters; possibly some damping effect was produced by putting them together.

H. H. Barnes, Jr.:—The speaker believes the problem we have in this country, or which we have had, of getting alternators with heavy fly-wheels to operate properly together, has been somewhat of a special problem. They have not had the same difficulties abroad. They favor somewhat lighter wheels as a general thing in Europe, a fact that is partially explained by the number of three-crank engines installed as prime movers. In Europe, therefore, the question of resonance has been the more important one, whereas with us it has been cumulative surging. In this country the speaker knows of one plant only in which there is actual trouble due to resonance under operating conditions. He has not visited this plant, and is not able to speak from personal experience, but understands it is well nigh impossible to operate the machines in multiple. The natural frequency at normal pressure is 92 per minute; and there are 100 revolutions per minute; therefore we have a ratio of frequencies of 0.92, which is too close to unity to allow of satisfactory running.

Discussion on "The Single-Phase Induction Motor."

W. S. Franklin:—The speaker regrets very much that Mr. Steinmetz is not present, as he had hoped to draw him out in the discussion of the paper by referring to what seems to be

a serious defect in Mr. Steinmetz's papers on the single-phase induction motor. The speaker does not think that Mr. Steinmetz has given us a really fundamental or basic theory of the single-phase induction motor. His papers of February, 1898, and January, 1900, are no doubt of very considerable value, but they are devoted almost wholly to the operation of various starting devices. In so far as starting devices change a single-phase induction motor into a polyphase induction motor, Mr. Steinmetz's theory and equations are correct; but it can hardly be said that he has given any theory at all of the characteristic activities of the single-phase induction motor, and what he has given is incorrect, in the opinion of the speaker.

Mr. Steinmetz's method is to approach the theory of the single-phase induction motor by making certain modifications of the equations of the polyphase induction motor. This method seems to complicate the theory unnecessarily, and the speaker does not see how Mr. Steinmetz can justify the modifications of polyphase theory which he makes in adapting it to the single-phase machine.

The theory of the single-phase induction motor given here approximates to the actual facts as closely as the so-called complete theory of the ordinary transformer and as closely as the so-called complete theory of the polyphase induction motor. These theories as ordinarily used by engineers for accurate calculations take account only of first-order effects of primary resistance, magnetic leakage, and core losses, the mutual disturbing influences of these things being always ignored, except only in a single case.

The speaker has refrained from giving the full algebraic development of the theory, thinking that an outline of the method of obtaining numerical results might be more intelligible; for the sake of clearness the vector diagram of the transformer is used as a basis, which in its application to the induction motor is usually called the Heyland diagram. The various aspects of the calculations as based on the Heyland diagram correspond exactly to the various aspects of the calculations as based upon pure algebraic developments.

The difference between this theory and that of Mr. Steinmetz may perhaps be best indicated by comparing the speaker's equation for torque with the corresponding equation of Mr. Steinmetz, and it should be kept in mind that this equation is a logical result in this theory, while the corresponding equation of Mr. Steinmetz is an assumption. Mr. Steinmetz's papers do not contain a theory of the single-phase motor.

This difference between Mr. Steinmetz and the speaker in regard to torque may be stated most clearly for the case in which magnetic leakage is assumed to be equal to zero. On this assumption Mr. Steinmetz finds torque to be proportional to $\left(n - \frac{n^2}{f}\right)$ where n is speed and f is primary frequency. The

correct expression for torque, however, for zero magnetic leakage, makes it proportional to $\left(\frac{n-n^2}{f^2}\right)$. Both expressions give zero torque at standstill and at synchronism, but the correct expression gives maximum torque at 1/3 synchronous speed while Mr. Steinmetz's expression gives maximum torque at 1/2 synchronous speed, magnetic leakage being zero.

The speaker does not agree at all with Mr. Steinmetz on the question of magnetizing current; the statements in the paper regarding magnetizing current do not result directly from the speaker's fundamental equations, and therefore any one who accepts the derivation of the fundamental equations may think as he pleases concerning the magnetizing current. The speaker is, however, pretty sure that the cross-magnetizing current in the motor represents the flow of energy from kinetic energy of rotor to magnetic energy of cross flux and back again, and therefore that this cross magnetizing has no influence upon the primary current, if the rotor is heavy, except in so far as it is not wattless, and to the extent that it is not wattless it creates a back torque which increases the load current in the primary exactly as a belt load would.

The idea of the carrying of the induced rotor currents around by the armature, because of their supposed time lag in phase, thus enabling them to produce the cross flux, is utterly wrong. Properly all phases should be referred to *primary current*, not to primary electromotive force, and if there is no great amount of core reluctance we know that the currents induced in the rotor windings by the pulsations of the main flux Φ are exactly in phase both in space and in time with the stator or primary current. It is only through the mediation of e.m.f. produced by rotation that a current can be produced in the rotor windings which is out of phase either in time or space with the primary current.

The speaker wishes to make a further statement in justice to Mr. Steinmetz; that Mr. Steinmetz does not pretend that his papers on induction motors supply a physical analysis of the activities of the single-phase motor proper. Those of you who have read these papers, of course, know that more than nine-tenths of the discussion and developments apply simply to the behavior of the motor with various starting devices, and of course, in that case, the motor being really, to a great extent, a polyphase motor, the theory of the polyphase motor does actually apply.

[COMMUNICATION AFTER ADJOURNMENT.]

A. S. MCALLISTER:—On page 427 of his paper Professor Franklin says: "When a two-phase induction motor has one of its stator windings detached from the source of supply, thus becoming a single-phase motor, the wattless component of the magnetizing current in the remaining stator winding is unchanged in value and the power component of this magnetizing

current is doubled." Experiments show that, under the conditions assumed, both the power and the wattless components of the current in the active primary winding are increased; the former being slightly more, and the latter slightly less than doubled. Thus, with a certain two-phase induction motor, operating without load at full speed, the following observations were made:

	PHASE A			PHASE B			CALCULATIONS—PHASE A			
OBS.	E	I	W	E	I	W	Cos ϕ	Sin ϕ	I cos ϕ	I sin ϕ
(1)	165	11.7	397	165	11.7	397	.203	.979	2.41	11.45
(2)	165	21.7	930	137	0	0	.259	.966	5.63	20.95

The active winding of the motor, in any case, forms the primary of a stationary transformer of which the exciting current must possess sufficient magnetomotive force to maintain the value of flux demanded by the impressed e.m.f. While the current in the rotor, which produces the flux in exact mechanical quadrature to the primary magnetism, has truly no component magnetomotive force to affect the primary magnetism, and the assumption of no space lag of such current is more or less in accord with facts, it is not proper to neglect the fact that the counter e.m.f. of rotation of the conductors of the secondary of the transformer through the flux produced by the exciting current in the rotor is in time-phase with such flux, and that the additional current which flows in the rotor conductors due to the difference between the transformer e.m.f. and this counter e.m.f. has a component of opposing magnetomotive force which materially affects the current required to maintain the primary field.

Discussion on "Wave-Form-Variations of a Long-Distance Line."

The President:—The Chair would say that it seems to be difficult to get any accurate information from these companies operating on the Pacific coast, and as they have had the most general experience, whenever we can get any information from them we consider ourselves somewhat fortunate. It seems to be their policy, however, to keep their troubles to themselves, which is not a bad policy sometimes.

A paper presented at a Meeting of the American Institute of Electrical Engineers, Seattle, Wash., April 14, 1904.

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OPERATION OF SYNCHRONOUS CONVERTERS.

BY S. C. LINDSAY.

It is the purpose of this paper to give a history of the experience we have had with 60-cycle synchronous converters in Seattle during the last three years and a half. As the Seattle Electric Company has a greater capacity in 60-cycle synchronous converters in daily operation than any other company in the United States, and as they have been operated under a variety of conditions, the writer thinks that his experiences might be of interest to others who are operating the same class of apparatus.

In the summer of 1900 we put into service two 550-volt compound-wound synchronous converters which were supplied with alternating current from the Snoqualmie Falls Power Company, the direct current from these synchronous converters being used to operate street cars and stationary motors. At that time the Snoqualmie Company was transmitting to Seattle at 15 000 volts over two- to three-phase lines, the conductors for each line being No. 2 solid aluminum wire. It was originally planned to use one line for power and the other line for lighting and such power loads as were not subject to large and sudden changes. The current for the synchronous converters was transformed to 340 volts by three 500-kw. transformers connected in $\triangle$ on both sides.

With 15 000 volts on the lines and the lines in multiple, one synchronous converter would operate satisfactorily up to full load; when the second synchronous converter was put in they would begin to pump immediately, although the load would not be increased beyond the capacity of one synchronous converter. If both machines were left in circuit the pumping

would soon become so violent that the transmission line circuit-breakers at the power-house would open. Various adjustments of the field strengths between maximum and minimum improved matters very little. It was tried a number of times to operate two machines under this condition, but without success. At times there would be several hunderd horse power of induction motors in Seattle operating from the same system. We tried to operate the synchronous converters both with and without the induction motors in service, but without success, the results being a little more favorable with the induction motors running.

When the transmission lines were separated in Seattle, but still supplied from the same bus-bar at the power-house, we tried to operate a synchronous converter from one line and the induction-motor load and lights from the other line; with a very weak field a single synchronous converter would run comparatively steady without load, but would pump violently when loaded to one third of its rated capacity, especially if it were a street-railway load. With the lines divided as above two synchronous converters were synchronized on the same transmission line, but were not loaded nor even paralleled on the direct-current side. After running under this condition for a few minutes they began to pump, and the pumping soon became so violent that they had to be shut down.

After these results, no further attempts were made to operate two machines at a time until the power company began to transmit at 30 000 volts, when it was found that both synchronous converters would operate entirely satisfactorily up to their full capacity with the transmission lines in parallel, and when the lines were separated one synchronous converter would operate perfectly up to full load and 50% of overload, but when the second machine would be switched in pumping would commence unless the load was reduced. We could carry more load without any disturbance on one machine than we could on the two. It must be borne in mind that when these attempts were made to operate two synchronous converters from one line the line was loaded in almost every case with the induction motor and lighting load that was always carried when both lines were in parallel.

In the spring of 1901 a third 550-volt synchronous converter was installed in the same sub-station with the other two machines, and connected to the same bank of step-down trans-

formers. When the three synchronous converters were running at the same time they were, of course, in parallel on both their alternating-current and direct-current sides.

A 250-volt shunt-wound 500-kw. two-phase synchronous converter was also installed at the same time in another sub-station about one-qaurter of a mile from the station where the 500-volt synchronous converters were installed, and was operated from the same system.

The addition of these last synchronous converters caused no trouble whatever as long as both transmission lines were in parallel, but when it became necessary to place the entire Seattle load on one line it was found that the 250-volt synchronous converter and one 550-volt synchronous converter would operate satisfactorily, but that two 550-volt synchronous converters would not operate satisfactorily when the 250-volt synchronous converter was shut down.

When the transmission lines were multipled at Renton, and one line cut out between Seattle and Renton, all of the load in Seattle being carried by a single line between these two points and the two lines between Renton and the power-house, all of the 550-volt synchronous converters and the 250-volt synchronous converter could be operated at the same time; but when all of them were heavily loaded there was more or less pumping, but it was not serious enough to interfere with the lighting to any great extent. Within the last year the conductors in the transmission lines have been changed from No. 2 aluminum to 0000 aluminum between Renton and the power-house, and to 00 aluminum between Renton and Seattle. Since this change two or more 550-volt synchronous converters can be run from a single line without any trouble. The trouble experienced when first trying to operate more than one synchronous converter from a single line must have been due to excessive line drop which caused an interchange of current between the synchronous converters.

While operating the three 550-volt synchronous converters from the same bank of transformers it was necessary to use great care in adjusting their field rheostats so as to keep the load equally divided between the synchronous converters. If one synchronous converter was given a weak field and the other two a strong field, pumping would commence and soon become serious if the proper adjustment were not made. We had all three synchronous converters thrown out of synchronism several time

from improper adjustment of their field currents. While operating under this condition it was found that a dirty commutator or too much oil applied to a commutator for the purpose of lubrication would cause serious trouble, and on one or two occasions threw all machines out of synchronism. Shifting the brushes to find the neutral point was also a prolific source of trouble. After these causes of trouble had been discovered we got fairly good results, but only by the most careful attention to the machines.

Experience with these rotaries operating from one bank of transformers leads the writer to believe that a worse combination cannot be had, and is something that should never be done except as a makeshift.

After running under this condition for two months a separate bank of transformers was installed for each synchronous converter, each bank consisting of two 300-kw. transformers transforming from 2200 to 340 volts, these transformers in turn being connected to a single bank, transforming from 30 000 to 2200 volts, both transformations being made on the Scott two-phase to three-phase system. This change in no way affected the results of an attempt to operate on a single transmission line, but the troubles experienced from operating the three synchronous converters from a single bank of transformers were entirely removed.

The one thing that has caused more trouble than any other in the operation of synchronous converters, and the thing that has been responsible directly and indirectly for over 90% of all the troubles we have had with them, has been the frequent breaking down of the transmission line. Almost every time the line would break, all of the 550-volt synchronous converters then running would flash-over at the commutator, making a loud report very similar to the discharge of a cannon. The breaking of the line caused a rise of pressure at the commutator of the synchronous converters great enough to jump the space between the positive and negative brush-holders of the machines. There were only two or three cases when the line broke down that the flashing-over did not occur. On several occasions when the line broke armature coils were burned out simultaneously with the flash. The flashing did considerable damage each time it occurred, by burning the commutator and brush-holders and tearing away parts of the mica insulation between the copper segments, which left small pockets that soon filled up with particles of copper and carbon dust. Whether the rise of pressure

at the commutators was caused by the sudden opening of the line or by a short circuit between the broken wires and the other two line wires is a matter that has never been determined, as no one qualified to make an intelligent report was ever present at the point of trouble when a break occurred. This trouble was finally stopped by grounding the neutral point of the two-phase windings of the step-down transformers. Although this was done primarily for another purpose it produced an effect on the synchronous converters that we had long desired.

If the commutators are in first-class condition the damage done by a single flash has never been sufficient to cause serious trouble unless armature coils were burned out; the damage to the commutator being quickly removed by the use of a file and coarse sandpaper. When line troubles were quite frequent, say three or four times a week, the damage done to the mica segments by one flash would not be removed before another flash would occur, and the result was that a number of mica segments in each commutator would be wasted away from 1/32 to 1/16 an inch below the surface of the copper segment. These places would soon fill up with particles of carbon and copper dust, causing short circuits between segments. These short circuits would burn out, causing a flash and explosion at the commutators very similar to that caused by line troubles, the principal difference being that current did not disappear from the transmission line when trouble was caused by these short circuits. We experienced a great deal of difficulty from these short circuits before the cause of the trouble was determined. The difficulty in locating the trouble was due to the fact that when a flash-over would occur and throw the synchronous converter out of synchronism they could be immediately brought to voltage, synchronized, and loaded again without giving any evidence of the cause of the trouble. Sometimes the synchronous converters would be thrown out a number of times in a day from this cause, and again they would run for one or two days without any trouble. The cause of the trouble being determined, it was easily remedied by turning the commutators down until the mica and copper segments were even.

In the summer and fall of 1902 all of our synchronous converters were moved to the Post Street station, which had just been completed, and we now have in this station nine 500-kw. synchronous converters, five of which are 550-volt, three-phase, the other four being 250-volt, two-phase, which are used on the

three-wire lighting system. As stated previously, each synchronous converter is connected to its own bank of transformers, the transformers for the 500-volt synchronous converters being connected on the Scott system transforming from two-phase to three-phase.

The power purchased from the Snoqualmie Falls Power Co. is also delivered to this station, making it a combined generating and sub-station. The synchronous converters operate equally well from the steam-driven generators in this station without the use of special inductance coils as they do from the transmission lines, the only exception to this rule being when the steam-driven generators were operating considerably below their normal speed, say 114 rev. per min., their normal speed being 120 rev. per min. The action of the synchronous converters when run from the steam-driven generators at this reduced speed seems to be a tendency to slow down every time the engines pass their centers, which produces a very noticeable effect on all incandescent lights supplied from the generators and lighting synchronous converters. This trouble is caused by the irregular angular velocity of the prime movers and cannot be considered as synchronous converter trouble. In no case has this caused any trouble other than the effect on the incandescent lamps, even when the speed of the generators would fall as low as 110 and 112 rev. per min. As stated before, this effect entirely disappears when the generators are running at their normal speed.

During the last 18 months the transmission line troubles have been very much less than they were before, and the troubles with the synchronous converters have practically disappeared. As the grounding of the neutral point of the secondary winding of the step-down transformers prevents the synchronous converters from flashing-over at the commutators when line trouble does occur, and various other improvements have been made in the transmission line, we have not had any more trouble with these synchronous converters than would be had with an equal number of direct-current generators of the same capacity.

Having the two sources of supply in the same station, where all of the synchronous converters are located, it has been necessary to operate some of the synchronous converters from the steam-driven generators and some of them from the power supplied by the Snoqualmie Falls Power Co., all synchronous converters being operated in parallel on the direct-current side. This combination is used with both types of synchronous con-

verter, the pressure of each synchronous converter being controlled by Hartford regulators. This arrangement serves to steady the pressure variations caused by the fluctuations of the street-railway load, and the results are very much more satisfactory for smoothing out the load, than when all synchronous converters are operated from the same source of supply.

As for care and attention necessary for synchronous converters, it is substantially the same as that required by direct-current generators of the same pressure and capacity. The commutators require sandpapering about once a week. Occasionally a commutator will require sandpapering twice in one week. No. 2½ sandpaper is used to bring the commutator to a smooth surface, and it is then finished with No. 1 sandpaper. A small amount of oil is used on each sheet of sandpaper to prevent the dust from flying. It is very bad practice to saturate sandpaper with oil for use on a commutator, as the excess of oil will form a paste with the copper dust that will be forced into the mica, if the mica is as soft as commutator mica should be. The excessive use of oil is especially bad if there happens to be a number of mica segments in a commutator that are not uniformly even with the copper segments. Very good results are obtained by spreading the oil evenly over the sandpaper, then absorbing the greater portion of it with clean waste, leaving enough to prevent the copper dust from flying, but not enough to form a paste.

We have tried for a long time to get a carbon brush that would be satisfactory, and we think that we have found one. In the meantime we have found a great many that were not satisfactory, the average life of a set of carbon brushes being from three to six months. We have a set of brushes in a synchronous converter that were put in the 28th of last May, and they are about half worn out. The wear on this commutator has been very small also. We have a set of brushes in another machine that has been in use since February 23, and the wear on these brushes was found to be about 3/16 of an inch when measured to-day. The brush just mentioned is a medium-soft brush with a good deal of graphite in it. Pure graphite brushes are not at all satisfactory for synchronous converters.

OBITUARY.

Francis Forbes, the lawyer, died suddenly of pneumonia at his home, No. 8 West Fifty-sixth St., New York, February 18, 1904. Mr. Forbes was born in Rochester, N. Y., in 1846; he was graduated from Rochester University in 1865, and from Columbia Law School in 1870.

Mr. Forbes was for the last ten years senior member of the firm of Forbes & Haviland. He was a member of the University Club, the Lawyers' Club, and of the American and State Bar Associations. Mr. Forbes was a recognized authority on trademark law, and represented this country at the International Convention of Industrial Marks in Madrid in 1890, and later at Brussels in 1897. He was also a member of the State Constitutional Convention in 1894. He was recently appointed by President Roosevelt a delegate to the International Convention of Jurists, to be held in connection with the World's Fair at St. Louis in September of this year. He was a deacon and trustee of the Fifth Avenue Presbyterian Church for many years. He was elected an Associate of the AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS, September 16, 1890.

Mr. Forbes leaves a widow, daughter of the late Robert Bonner; two sons and two daughters.

John B. O'Hara, associate editor of the *Street Railway Journal*, died in Rochester, N. Y., March 13, 1904. Mr. O'Hara was born in Rochester on December 10, 1865, and was engaged for the greater part of his life in technical journalism.

After being graduated from the public schools of Rochester, he was connected with the Rochester *Herald*, and was afterwards appointed associate city editor of the *Post-Express*. In 1889 he went to Chicago to join the editorial staff of the *Western Electrician*, and was later appointed editor-in-chief of that paper. This position he occupied for a number of years with marked success. Later he was offered a proprietary interest and business management, with editorial control, of *Modern Machinery*, a monthly paper published in Chicago and devoted to the machine-tool interests. Failing health compelled him to resign this position and take a long vacation, part of which was spent in Rochester and part in the South. Partially recovering, Mr. O'Hara joined the staff of the Westinghouse Companies' Pub-

lishing Department, with headquarters in New York. After a few months' connection with this company he was offered and accepted a position on the editorial staff of the *Street Railway Journal*, which he occupied at the time of his death.

Owing to his connection with the technical press in both the East and the West, he had a wide acquaintance in electrical circles. He possessed the respect and esteem of all who knew him, and especially of his immediate associates, who had an exceptional opportunity of appreciating his high character and exceptional qualities of mind and heart.

As a writer, Mr. O'Hara had a clear style of expression, with the faculty of going to the foundation of his subject, and a keen perception of the news feature of every item.

In 1894 Mr. O'Hara married Miss Margaret Hickey, of Rochester. He is survived by an only son, aged eight years.

Mr. O'Hara was elected an Associate of the AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS, January 23, 1903.

Chester Delos Crandall was born at Sackett's Harbor, N. Y., and died March 22, 1904. Mr. Crandall was in every sense the builder of his own career. An excellent academic education obtained in his home schools, prepared him for entry in the University of Rochester, N. Y., from which he graduated with honors and distinction in 1879. He at once went to the Western Electric Manufacturing Company at Chicago, at the instance of Mr. E. M. Barton, who had known him from boyhood; at the time of his death he was still with the same company, making a continuous business connection of a quarter of a century, interrupted by two brief absences, one with the Gilliland Electric Manufacturing Co. until its absorption by the Western Electric Co., the other as secretary of the Missouri and Kansas Telephone Co.

Mr. Crandall's acquaintance in the electrical profession was wide, due principally to extensive business trips, and necessary dealings with many people, none of whom could resist his quiet charm and sincerity. Mr. Crandall was elected an Associate of the AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS, September 27, 1892.

Theodore E. Theberath was born, November 22, 1863, at Newark, N. J., and died March 29, 1904, at San Francisco, Cal., after a brief illness. He was prepared for college at the Stevens

High School, entered Stevens Institute in the fall of 1884, and was graduated in 1888 with the degree of Mechanical Engineer. He spent the first six months after graduation studying experimental mechanics in the laboratories and shops of Stevens Institute.

On January 1, 1889, he was employed as detail draughtsman by the United States Electric Light Company. After the taking over of this company as part of the Westinghouse Electric and Manufacturing Company in April 1, 1889, he was transferred to the Newark factory of the Westinghouse Electric and Manufacturing Company and given general charge of testing and construction work. While in this position Mr. Theberath directed the installing of the first two large generators for the Pittsburg Reduction Company, for the reduction of aluminium. This installation consisted of two generators, each having a capacity of 2500 amperes at 60 volts; they were operated in multiple and were the beginning of the great plant now operated at Niagara Falls by this company.

In February, 1890, he installed several Westinghouse plants in West Virginia for operating coal-cutting machinery in the soft-coal mines. In August, 1891, he installed the electrical apparatus for the concentration of magnetic iron-ore at the mill of the New Jersey Magnetic Concentrating Company, located in the Adirondack Mountains.

In December, 1891, he was appointed chief electrician of the Newark branch of the Westinghouse Electric and Manufacturing Company. While in this position he devoted his energies to the design of special generators and crane motors. On October 1, 1892, he quit engineering work and entered the employ of the Ansonia Electric Company, of Chicago, as special sales agent for Stanley transformers. On the dissolution of the Ansonia Electric Co., October, 1893, he joined the staff of the Weston Electrical Instrument Company at Waverley Park, N. J., and was put in charge of the standardizing department. On August 1, 1894, he resigned this position to become associated with the New York office of the Stanley Electric Mfg. Co. as engineer and salesman. Two years later, in August, 1896, he was transferred from New York to the Pacific Coast and appointed electrical engineer for Messrs. Jno. Martin & Co., western representatives of the Stanley Electric Manufacturing Company and other well-known concerns. His initial work in this capacity was the construction of the transmission plant of the Blue Lakes Water

Company, by means of which 1500 horse power was distributed to the towns along the Mother Lode in Amador and Calaveras counties.

Shortly after, and upon the inception of the Yuba Power Company's transmission system from Brown Valley to Marysville, Mr. Theberath became identified with the Yuba Company as constructing engineer. At the time of his death Mr. Theberath was consulting electrical engineer for this system, a system which has proved to be one of the two direct forerunners of the great transmission system of the California Gas and Electric Corporation, popularly known as the Bay Counties System.

He was the engineer of the original plant at Colgate, known as Colgate Power House, No. 1, and which embraces practically one-half of the generating station bearing that name. Subsequently, many months were spent by him in the exploration of water rights that were geographically located so as to be tributary to the Bay Counties development, and while engaged in this work he was largely instrumental in deciding upon the location of the Nimshew plant as well as of the French Creek plant.

Mr. Theberath has contributed valuable papers to the Pacific Coast Transmission Association, and he was always an active participant in the discussions. When stricken with his last illness he was engaged in writing a paper for the AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS which would have given the concentration of his large experience in the building and operating of long-distance, high-pressure pole lines in California. He was elected an Associate of the AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS on March 23, 1898, and was transferred to the grade of Member on June 24th of the same year.

Physically Mr. Theberath was endowed magnificently, and his deep love for "my mountains" as he reverentially termed them, bespoke his passion for the wilds.

He was buried on April 1 with Masonic honors at Cypress Lawn, and his funeral was marked by the attendance of those who are most prominent in the transmission industry in California.

Alvah Ward Underwood was born August 12, 1875, at Toronto, Ontario, and died at San Antonio, Texas, May 4, 1904.

He was educated in the public schools of New York State. In 1890 he entered the students' course of the General Electric Company at Schenectady, remaining three years. In 1893 he

joined the engineering staff of the Otis Elevator Company at Yonkers, N. Y., making a specialty of safety-appliances and methods of control connected with electric and hydraulic elevators.

In 1896 he removed to Mexico to engage in engineering and contracting business. In 1898 he enlisted in Company E, First U. S. Volunteer Engineers, and served through the Porto Rico campaign of the Spanish-American war.

He returned to the Otis Elevator Company at the close of the war and remained there until 1902 when he entered the employ of the Stanley Electric Mfg. Co. at Pittsfield, Mass. Poor health caused him to resign this position. After a short stay in the Adirondacks he moved again to Mexico and from there to San Antonio, Texas.

Mr. Underwood was elected as Associate of the AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS, March 27, 1903.

ASSOCIATES ELECTED JUNE 15TH, 1904.

Name.	Residence.	Endorsers.
ADAMS, CHARLES FRANCIS,	Electrical Engineer, Stanley Electric Co., Pittsfield, Mass.	D. B. Rushmore. C. C. Chesney. F. A. C. Perrine.
BAKER, I. FRALEY,	Superintendent's Office, Sprague Electric Co.; res. 18 South Clinton St., East Orange, N. J.	Robert Lundell. Fred. Darlington. C. E. Carpenter.
BATSON, WALTER VENNARD,	Electrical Engineer, Hollis French and Allen Hubbard; res. 12 Platt St., Boston, Mass.	J. W. Cowles. W. L. Puffer. J. I. Ayer.
BAUER, HENRY NICHOLAS,	Cable Electrician, Postal Telegraph Cable Co.; res. Hasbrouck Heights, N. J.	F. W. Jones. J. F. Skirrow. M. M. Davis.
BENNETT, CHARLES EDWARD,	Inspector, Allegheny County Light Co., of Pittsburg, Room 303, Philadelphia Building, Pittsburg, Pa	N. C. McPherson. F. R. Wilson. Philander Betts.
BERRY, CLYDE ALBION,	Telephone Engineer, Western Electric Co., 463 West St.; res. 271 West 113 St., New York City.	M. E. Chester. O. A. Bell. F. L. Gilman.
CARMAN, CHARLES WHITNEY,	Partner, Charles Whitney Carman & Co., 657 Railway Exchange, Chicago, Ill.	G. A. Damon. F. B. Badt. R. W. Pope.
CARROLL, MORRIS B.,	Student, Stevens Institute, Hoboken, N. J.; res. Warwick, N. Y.	W. F. White. A. F. Ganz. D. S. Jacobus.
COLEMAN, S. WALDO,	Tester, General Electric Co.; res. 618 Chapel St., Schenectady, N. Y.	Charles Gilcrest. F. E. Cooley. George Goldman.
COLLINS, EDGAR FRANCIS,	Foreman, Testing Department, General Electric Co., Scheneetady, N. Y.	William Esty. E. B. Raymond. R. W. Pope.
DALTON, NELSON WAIT,	Electrical Engineer, Hartford Carpet Corporation, Thompsonville, Conn.	J. C. Lott. August Parshall. A. D. Babson.
DEAN, ERNEST WILLIAM,	Resident Engineer, Havana Electricity Co., Ltd., Havana, Cuba.	H. A. Lardner. H. W. Reilly. J. W. McCrosky.
FERRIN, ARTHUR W.,	Chief Electrician, American Locomotive Co., Schenectady, N. Y.	R. N. Williams. A. L. Clough. J. B. Smith.

FOGARTY, JOHN P., Citizens Telephone Co.; res. 1011 City Park Ave., Columbus, O.	M. C. Hull. F. C. Caldwell. L. G. White.
FOY, JOHN DREWRY, Assistant Electrical and Mechanical Engineer, Ford Bacon and Davis, 2501 5th Ave., Birmingham, Ala.	R. A. White. G. H. Harris. H. J. Ryan.
GAILLARD, LAWRENCE LEE, Electrical Engineer, Interborough Rapid Transit Co.; res. 209 West 97 St., New York City.	H. G. Stott. L. B. Stillwell. C. R. Cross.
GARDENER, WILLIAM R., Assistant Manager, Pittsfield Electric Co., Pittsfield, Mass.	J. J. Kline. F. A. C. Perrine. C. C. Chesney.
GIBBS, GEORGE SLOCOMB, Sales Engineer, Westinghouse Electric and Mfg. Co., 716 Board of Trade Building, Boston, Mass.	F. S. Perry. P. W. Davis. C. L. Abbott.
GILMORE, JONATHAN MONROE, Foreman, Testing Room, Stanley Electric Mfg. Co.; res. 13 Broad St., Pittsfield, Mass.	D. B. Rushmore. C. C. Chesney. F. A. C. Perrine.
GLENN, WILLIAM HARPER, Superintendent Roadways, Georgia Railway & Electric Co., 24 E. Alabama St., Atlanta, Ga.	A. M. Schoen. W. R. Collier. R. W. Pope.
HADFIELD, RAY HARRISON, Instructor Iowa State College, Ames, Iowa.	D. C. Jackson. B. V. Swenson. F. P. Woy.
HEMPHILL, WILLIAM, Draftsman, Cataract Power & Conduit Co., 811 7th St., Buffalo, N. Y.	DeLancy Rankine. H. B. Alverson. E. P. Harder.
HIBBARD, TRUMAN, Chief Engineer, Electric Machinery Co., 124 West Grant St., Minneapolis, Minn.	E. P. Burch. G. D. Shepardson. F. W. Springer.
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JONES, ALFRED HOWARD, Salesman General Electric Co., Empire Building, Atlanta, Ga.	A. M. Schoen. E. H. Ginn. W. H. Hillman.
JONES, BUDD J., Construction Engineer, Sargent Lundy; res. 555 45th Place, Chicago, Ill.	A. D. Lundy. L. S. Boggs. James Lyman.
KETTERING, CHARLES FRANKLIN, National Cash Register Co., Dayton, O.	F. C. Caldwell. B. F. Thomas. F. A. Fish.
LATEY, HENRY NELMS, Assistant Electrical Engineer, Interborough Rapid Transit Co., 13 Park Row, New York City.	F. B. H. Paine. Calvert Townley. L. B. Stillwell.
LAWTON, JOHN HENRY, Instructor, Iowa State College, Ames, Iowa.	G. W. Bissell. B. S. Lanphear. H. W. Dow.
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MORGAN, CHARLES CALDWELL, Manager, Stanley Electric Mfg. Co.; res. 150 West 104 St., New York City.	Norman Ross. F. A. C. Perrine. C. C. Chesney.
MORRIS, ANTHONY SAUNDERS, Engineer and Salesman, Westinghouse Electric Mfg. Co., 708 Land Title Building; res. 1006 Clinton St., Philadelphia, Pa.	C. F. Scott. L. B. Stillwell. C. A. Bragg.
MORTON, ALEX AMERTON, Stanley Electric Mfg. Co.; res. 142 Appleton Ave., Pittsfield, Mass.	J. J. Kline. H. H. Barnes. D. B. Rushmore.
PERRY, ALEXANDER, Salesman, General Incandescent Arc Light Co., Pittsfield, Mass.	J. J. Kline. H. H. Barnes. D. B. Rushmore.
PIELSTICKER, FRED ALONZO, Student, Iowa State College; res. Carroll, Iowa.	B. S. Lanphear. L. B. Spinney. G. W. Bissell.
PLAYTER, OWEN BAXTER, Assistant, Seattle Electric Co., 1134 North Broadway, Seattle, Wash.	E. G. Allen. L. C. Lindsay. D. P. Robinson.
RAWSON, HOBART, Electrical Engineer, Cincinnati Gas & Electric Co.; res. 3737 Clifton Ave., Cincinnati, Ohio.	J. H. Hallberg. Darrow Sage. C. A. Adams, Jr.
SCOTT, ALEXANDER HUGH, Student, Iowa State College, Box 779, Ames, Iowa.	B. S. Lanphear. L. B. Spinney. F. L. McClain.
STOKES, HUGH GREGORIE, Engineer Aid, U. S. Geographical Survey, Livingston, Ariz.; res. Early Branch, S. C.	W. M. Riggs. H. A. Storrs. R. W. Pope.
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WATSON, RICHARD CARR, Assistant Regulator, New York Edison Co.; res. 147 W. 128 St., New York City.	W. T. Fernandez. W. F. Wells. H. W. Leitch.

WEAVER, AMOS SHELDON, Student, General Electric Co.; res. 80 Park St., West Lynn, Mass.	G. E. Sanford. E. E. Boyer. R. T. Brooke, Jr.
WEHRLEY, EDWARD JUSTUS, Special Agent, American Telephone & Telegraph Co., 15 Dey St., New York City; res. East Orange, N. J.	H. V. Briesen. R. E. Chetwood, Jr. J. W. Stickney.
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WILLIAMSON, ALFRED, Assistant Testing Department General Electric Co.; res. 110 W. 91 St., New York City.	F. J. White. F. B. Crocker. G. F. Sever.
WILLS, HARRY LEVAGUE, Electrical Engineering Department, Georgia Railway and Electric Co., 24 E. Alabama St., Atlanta, Ga.; res. Kirkwood, Ga.	Abe Balsley. F. M. Layton. A. M. Schoen.

Total, 54.

Associates transferred to the grade of Member.

BARCLAY, JOHN C., Assistant General Manager, Western Union Telegraph Co., New York City.

RICHEY, ALBERT S., Electrical Engineer, Indiana Union Traction Co., Anderson, Ind.

TORCHIO, PHILIP, Engineer of Distribution, New York Edison Co., New York City.

ASSOCIATES RECOMMENDED FOR TRANSFER BY BOARD OF EXAMINERS, JULY 6, 1904.

LOUIS ALOYSIUS FERGUSON, General Superintendent Edison Co., 139 Adams St., Chicago, Illinois.

THOMAS LODWICK MILLER, Consulting Engineer. Tower Buildings, Liverpool, England.

HOWEL HENRY BARNES, JR., Traveling Engineer, Stanley Electric Manufacturing Co., Pittsfield, Mass.

APPLICATIONS FOR ELECTION.

Applications have been received by the Secretary from the following candidates for election to the INSTITUTE as Associates, and will be considered by the Board of Directors at a future meeting.

Any Member of Associate objecting to the election of any of these candidates should so inform the Secretary before August 26, 1904.

4016 Charles J. Quinn, Jr., Brooklyn, N. Y.
4017 Thomas L. Morrill, Bisbee, Arizona.
4018 James A. Scott, St. Louis, Mo.
4019 David L. Linguist, Yonkers, N. Y.
4020 Gian G. Ponti, Pittsfield, Mass.
4021 Albert S. Lindstrom, St. Louis, Mo.
4022 Carl J. Keifer, Schenectady, N. Y.
4023 Sydney R. Inch, Missoula, Mont.
4024 John A. Shaw, Montreal, Canada.
4025 Albert B. Storms, Ames, Iowa.
4026 Frank W. Linebaugh, Ames, Iowa.
4027 Torsten Holmgran, Stockholm, Sweden.
4028 Albert E. Hayes, Lynn, Mass.
4029 W. H. Hill, Brooklyn, N. Y.
4030 Harold V. H. Neefus, E. Orange, N. J.
4031 E. Vernon Murphy, Baltimore, Md.
4032 William E. Richards, Toledo, Ohio.
4033 John F. Card, Three Rivers, Mich.
4034 Matthew F. Maury, Lynn, Mass.
4035 Ferdinand Sieber, Philadelphia, Pa.
4036 Louis Cassier, Bridgeport, Conn.
4037 David M. Sivink, Durham, N. C.
4038 John C. Parker, Niagara Falls, N. Y.
4039 Lewis T. Robinson, Schenectady, N. Y
4040 Leonard Kebler, Bronxville, N. Y.
4041 Albert J. Kohler, Lynchburg, Va.
4042 Charles Bunje, Jr., Jersey City, N. J.
4043 Robert P. Parrott, New York City.
4044 Walter M. Dann, Wilkinsburg, Pa.
4045 Richard H. Thomas, New York City.
4046 John I. Beggs, Milwaukee, Wis.
4047 Charles E. Warner, Pittsburg, Pa.
4048 Ellery B. Paine, Woodstock, Conn.
4049 Thorsten L. Axelsson, Southport, Eng.
4050 Arion S. Kalenborn, Tacoma, Wash.
4051 H. Allcock, Manchester, Eng.
4052 Halbert P. Hill, St. Louis, Mo.
4053 Rafael E. Martinez, San Francisco, Cal.
4054 William M. McAnge, Jr., Suffolk, Va.
4055 William Hoopes, Pittsburg, Pa.
4056 George E. Quinan, Electron, Wash.
4057 Walter E. Holland, E. Orange, N. J.
4058 J. William White, Arlington, Mass.
4059 Ashley P. Peck, Milwaukee, Wis.
4060 José M. Garza, Hoboken, N. J.
4061 Tom W. Bevan, Brazil, South America.
4062 Philip H. Trout, Jr., Staunton, Va.
4063 Robt. T. Andrea, Schenectady.

Total, 48.

NOTICE.

As usual, only ten numbers of the Transactions will be issued this year, the July and August numbers being omitted.

The September number will be issued the first week in September.

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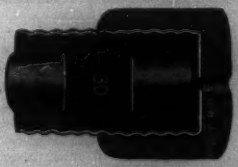

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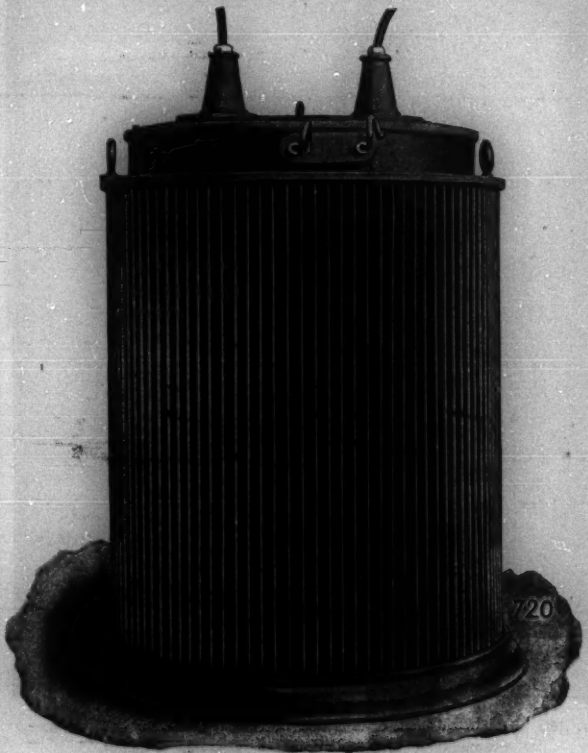

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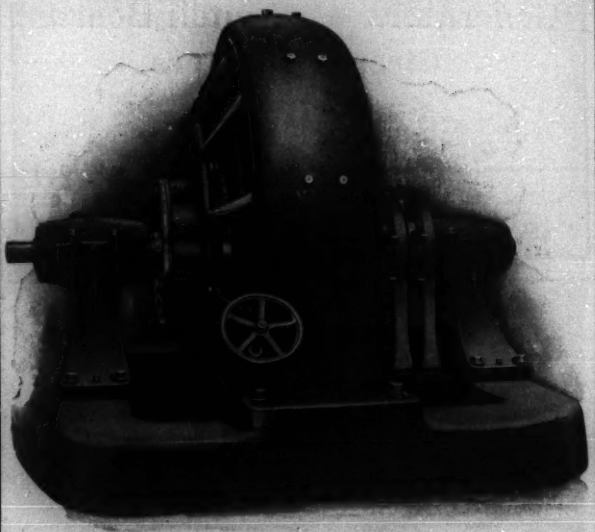

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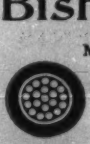

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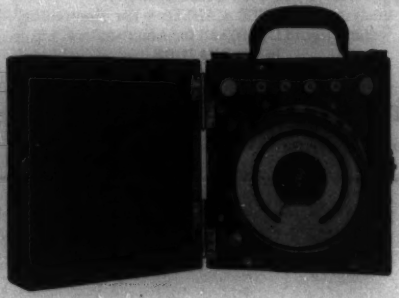

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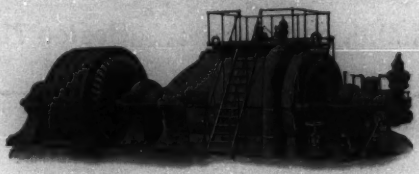

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